Fig. 47. The Gleaming-tailed Sea Dragon. *Idiacanthus fasciola* Peters. Nearly adult females (length, about 130 mm.) and adult males. Originally intended to illustrate post-larvae and adults, before their life histories were understood. (From a painting by Else Bostelmann). (*Frontispiece*).

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

Family IDIACANTHIDAE*

By William Beebe

(Figs. 47–81 incl.)

Contents

INTRODUCTION

§ For detailed data of nets, locality, dates, etc., concerning the capture of the deep-sea fish treated in this monograph, refer to Zoologica, Vol. XIII, Nos. 1, 2 and 3, and for physical data, methods of measurement and definitions of growth stages see Zoologica, Vol. XVI, No. 1.

* Contribution, New York Zoological Society, Department of Tropical Research, No. 437.

§ All the material under consideration was taken in the course of thirteen hundred and fifty nets, drawn in one locality, an eight-mile circle, with its center at 32° 12′ North Latitude and 64° 36′ West Longitude, nine and a quarter miles south-southeast of Non-such Island, Bermuda. Vertically this is an imaginary cylinder, considered as extending from the surface to the bottom of the sea, an extreme range of fifteen hundred fathoms.

§ Exact depth levels of the nets are confirmed by the use of a reliable deep-sea pressure gauge (Bull. N. Y. Zool. Soc., Vol. XXXIII, No. 6, p. 244). As before, six metre-nets are used, strung at exact intervals along two miles of wire, drawn at an angle of thirty degrees, at the rate of two knots an hour.

§ In the preparation of this paper I have had the coöperation of my whole staff, Mr. Tee-Van in the original supervision of the capture of the deep-sea fish, Miss Hollister in the production of the cleared and stained preparations and the study and description of the tail fin and caudal region, and Miss Crane in the elaboration of the host of data. The drawings are the painstaking work of Mr. Edward Delano. Except where otherwise indicated in the captions, all were made from Bermuda specimens of *Idiacanthus fasciola*.

SUMMARY OF IMPORTANT POINTS

§ Rearrangement of Taxonomic Relationships: Most of the fish hitherto classified under the genus *Stylopthalmus* in the family Stylophthalmidae have proved to be the larvae of *Idiacanthus* of the family Idiacanthidae.

§ Stalked Eyes in Young. This character is not uncommon among invertebrates (shrimps, crabs, squids, gastropods) and is occasionally found in other groups of fish such as *Bathylagus*. In the present larvae it is carried to an extreme and is only analogous to the other stalk-eyed species, the origin of the cartilage being quite different. The character is a very specialized one, correlated with many primitive conditions of teeth and skeleton.

The change into sessile-eyed post-larvae is by absorption of the optic nerve, and the drawing down and coiling up of the cartilage stalk, followed by its inclusion into the anterior part of the eye-socket, its complete covering with epithelium and final absorption.

§ Sexual Dimorphism. The adult males are larvoid, having the following characteristics: one sixth as large as adult females, paler, post-larval in proportions of body, head, eye and snout; lacking teeth, pelvic fin and barbel; having long caudal fin; bones slightly or not at all ossified, of simple, larvoid shapes and relative positions; digestive apparatus useless and atrophied subsequent to post-larval stage; testicles precocious in development, commencing to swell during post-larval period; an apparently intromittent organ present, supported by the specialized first five rays of the anal fin. The only highly specialized, non-juvenile organ is the huge post-orbital light, the corresponding structure in the female being minute.

§ Specialized Feeding Adaptations of Adult Female. An unossified first vertebra permits considerable upward thrust of the upper jaw and entire skull, and long, elastic, ligamentous connections between the four ceratobranchials and epibranchials allow very great distension of the entire throat.

Early powers of prehension are insured by the precocious basibranchial fangs, which develop before the permanent jaw teeth.

§ Ecology. The breeding season of *Idiacanthus fasciola* is in the late summer. The larvae swim in schools at relatively shallow depths (ca. 100 fathoms), while subsequent stages are not trawled above 500 fathoms. One adult seen at 200 fathoms from Bathysphere.

Throughout development, local tissue activity is invariably indicated by the presence of an unusual amount of pigmentation, concentrated temporarily at the exact area.

§ Conjectures and Unsolved Problems. The adult males may be said to be parasitic, judged by their great numerical abundance, small size and larvoid characters. Their weak swimming powers and huge cheek lights would indicate that they are of the nature of passive reflectors, with the females doing the seeking, conditions reversing those existing between the sexes of fireflies.

The occlusion of the digestive trace necessitates some other form of nourishment, such as absorption of the liver, and narrows the period for the possible finding of a mate. The external generative organ, which I have tentatively called intromittent, is so closely attached to the anal fin by membrane, that actual insertion into the body of the female appears difficult, even disregarding the fact of the oviparity of the species. But I cannot account otherwise for the presence of such an elaborate and large-sized organ.

Suborder STOMIATOIDEA

Oceanic Isospondyls differing from the Clupeoids in the presence of photophores. Soft-rayed fishes with pectoral fins placed low, pelvics abdominal, mouth terminal, laterally cleft; maxillary entering gape and toothed; gill openings wide.

Family IDIACANTHIDAE

Idiacanthidae Gill (Goode and Bean 1895)
Stylophthalmidae (*partim*) Jordan 1923

Stomiatoid fishes closely related to the Melanostomiatidae, but differing in the following particulars: form very elongate; dorsal and anal fins long and low, the dorsal originating well in front of the middle of the body, the anal about three-fifths as long, both fins extending almost to caudal base; a pair of protruding lateral spines at the base of each dorsal and anal ray; unique luminous organs at base of caudal fin; sexual dimorphism extreme, the mature males being less than one-sixth as large as breeding females, and larvoid or post-larvoid in almost all characters except those of the reproductory system; larvae with stalked eyes. In common with the Melanostomiatids the Idiacanthids have the following characters: scales absent; teeth highly developed (but in female only); caudal fin very short (female only), forked, the ventral lobe the longer; postorbital organ present; barbel present (female only); serial photophores without lumen or duct, present as usual upon branchiostegal membrane and in a lateral and ventral series on each side; premaxillaries with pointed process anteriorly extending upwards and backwards over mesethmoids; one supplemental maxillary; parietals absent; gill-rakers absent; long, black caecal stomach present (female only) connected anteriorly by a short arm with the straight intestine; two pyloric caeca; membrane present connecting lower jaw with hyoid arch. As in some Melanostomiatids, pectorals absent, except in young, and gill arches toothless. No adipose fin.

Oceanic and deep-sea fish of cosmopolitan distribution.

Only one genus is known, containing about five species.

The Bermuda Oceanographic Expeditions captured 129 specimens, all belonging to a single species, *Idiacanthus fasciola*, including specimens hitherto referred to the family Stylopthalmidae. In the order of abundance of individuals in the nets this fish ranks seventh

among the 12 families of deep-sea Isospondyls represented in the collection and seventh also among the total of 41 Isospondylous genera. Hence this family is numerically comparable to both the Alepocephalidae and Bathylagidae (see Zoologica, Vol. XVI, Nos. 2 and 3), but far less abundant than most of the remaining families of Stomiatoid fishes, notably the Gonostomids and Sternoptychids.

Genus **Idiacanthus** Peters 1876

GENERIC CHARACTERS. With the characteristics of the family. Cleft of mouth slightly curved; mandible projecting; premaxillary and mandible with a single series of depressible, unequal, bicuspid teeth, some of which are elongate fangs; maxillary with one or two series of erect and a single series of minute oblique teeth; a single series of teeth on vomer, several teeth on each palatine and two pairs on basibranchials; pelvics present in female only, six-rayed, situated in advance of middle of body; dorsal 54 to 74, extending over posterior two-thirds of body (i. e., in female nearly to or in advance of pelvics); anal 34 to 49, shorter than dorsal; dorsal and anal rays wide-set except posteriorly; postorbital organ minute in female, enormous in male; barbel present in female only, 1.3 to 2.5 times length of head, and of almost identical structure in all species: stem black; bulb half as long as stem, only slightly swollen, tapering distally to a point, lightly pigmented; proximally the bulb has a pair of lateral, oblique, transparent expansions; distal to these are two similar flanges, one anterior and the other posterior; near the base of the bulb anteriorly is a short, tapering filament with a pair of small translucent lobes proximally and several minute luminous bodies distally, the first being largest.

In the structure of the head, teeth and skull *Idiacanthus* closely resembles the genus *Melanostomias*, while the curved lower jaw is similar to that of *Photonectes*. However, until it is proved that striking examples of sexual dimorphism and highly specialized larval forms, such as are found in *Idiacanthus*, occur also among the Melanostomiatidae the maintenance of a separate family is amply justified.

GEOGRAPHICAL DISTRIBUTION: The accompanying map (Fig. 48) shows the general localities where specimens of *Idiacanthus* have been taken. Five species are probably valid. *I. fasciola* is known from the North Atlantic, Indian, and far western Pacific Oceans—a wide range, but limited to the temperate and tropical parts of the

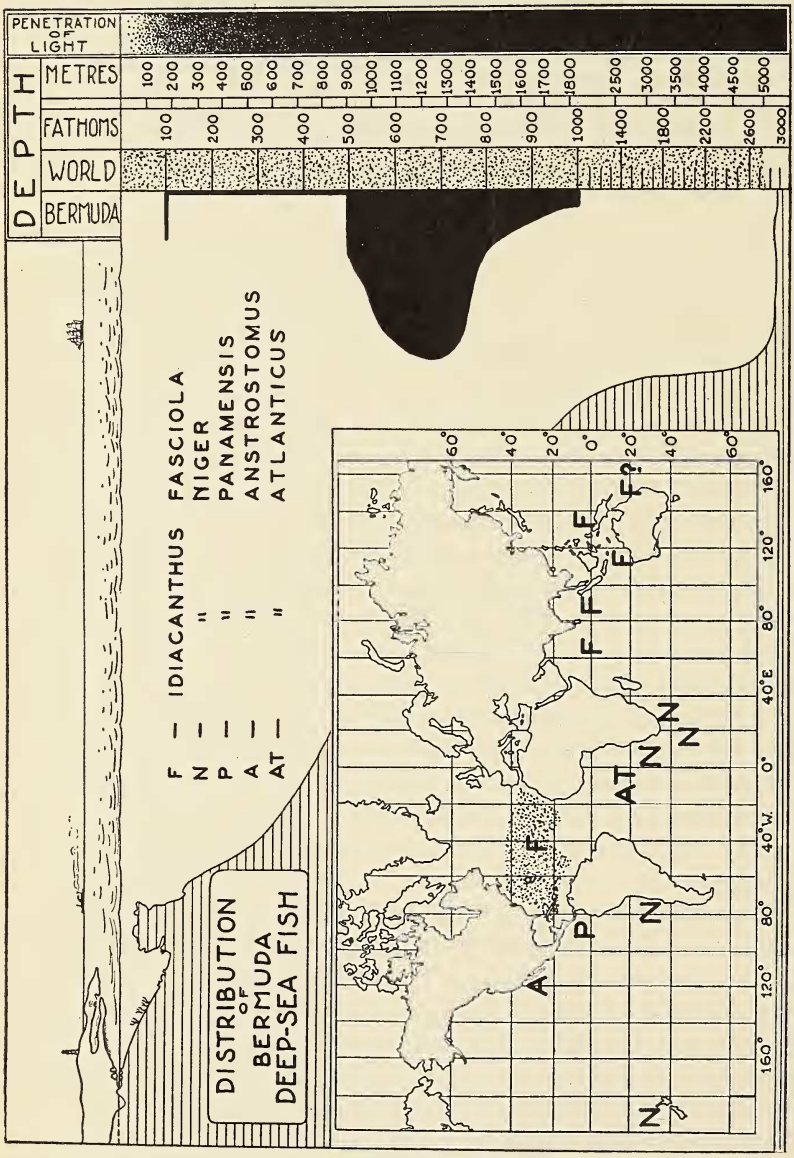


Fig. 48. The geographical and vertical distribution of the genus *Idiacanthus*. The relative number of specimens of *I. fasciola* taken at different depths by the Bermuda Oceanographic Expeditions is shown diagrammatically at the left of the column which gives the vertical range of the genus.

northern hemisphere and the warmer portions of the southern. *I. niger,* distinguished by the more anterior position of the pelvics, is confined entirely to the temperate parts of the southern hemisphere. *I. panamensis,* a species notable for the high development of its luminous tissue, has been taken only in the Gulf of Panama. The two remaining species, *I. anstrostomus* and *I. atlanticus,* from off California and from the southeastern Atlantic, respectively, are known only from single specimens. Of special interest is the dubius specimen taken off eastern Australia, as this locality is exactly between the ranges of *I. fasciola* and *I. niger.* This Australian fish was first described as *I. aurora* by Waite in 1916, subsequently (Regan, 1916) tentatively synonymized with *I. niger* and most recently (Regan and Trewavas 1930) with *I. fasciola.*

Brauer's records of *Stylophthalmus paradoxus* have been omitted from the map because, although *Idiacanthus* is undoubtedly included among his specimens, other forms are also present, and in his remarks on their geographical distribution he does not list separately the individuals taken in each locality. An inspection of the drawings and descriptions of stylophthalmine fish recorded by various other authors[1] shows that not one of their specimens can be *Idiacanthus.* Some of these have been already reidentified as the young of Myctophids (Sanzo, 1915, p. 133; 1920, p. 721), of *Eustomias* (Regan and Trewavas 1930, p. 73), and of *Bathylagus* (Taaning 1931, p. 272). Roule and Angel (1930, p. 55 ff.) suggested that the very dissimilar, stylophthalmine forms in their collection were all juvenile and even abnormal Myctophids; their illustrations show, however, that young Argentinids are undoubtedly represented in the series and probably Stomiatoids as well, and there seems to be no evidence that any of these specimens are monsters. Reëxamination of the Hudson Gorge specimens referred to *Stylophthalmus paradoxus* (Beebe 1929, p. 9) has resulted in the identification of the larger as an early postlarval *Idiacanthus fasciola.* The systematic position of the smaller is still uncertain.

DEVELOPMENT: The figures given under the heading "Postlarval examples of *Idiacanthus*" by Regan and Trewavas (1930, pp. 132–133) include both adolescent females and adolescent and adult males. The unequal development of the cheek light in the two

[1] Lo Bianco 1903, p. 167; Ehrenbaum 1905–1909, p. 360; Holt and Byrne 1907, p. 189; Mazzarelli 1912; Murray and Hjort 1912, p. 86, 746; Weber 1913, p. 16; Regan 1916, pp. 136–137; Roule and Angel 1930, pp. 50–56.

sexes has led to a number of hypotheses such as that of Regan: "we infer that the early post-larval fish live not far below the surface, that a little later they migrate to greater depths, 1000 metres or more below the surface, that the temporary increase in size of the eye and of the postocular luminous organ is an adaptation to a life in the depths. . . . The young fish may perhaps ascend to lesser depths."

It is now apparent also that the "nasal tubes" shown in the drawings of *I. panamensis* (*loc. cit.*, fig. 129A, D) are the damaged remains of larval eye-stalks of a young male and a young female respectively; as in a number of the Bermuda specimens, the stalks were broken off or their ocular ends torn loose before the normal process of close coiling and epithelial covering of the post-narial, preocular socket could be completed. The similarity of these immature and male specimens of *I. panamensis* to the corresponding forms of *I. fasciola* establishes without question the general occurrence of stalk-eyed young and larvoid males throughout the genus.

The small specimen described by Weber (1913, p. 15) is also a male.

A detailed account of the development of these fish resulting from the study of the Bermuda specimens commences on page 157.

Idiacanthus fasciola Peters 1876

Specimens taken by the Bermuda Oceanographic Expeditions

129 specimens; April to October, 1929 to 1931; 100 to 1000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; Standard lengths from 16 to 270 mm.

Specimens Previously Recorded

About 350 specimens; surface to 2750 fathoms; Atlantic, Pacific and Indian Oceans; 10? to 320 mm (possibly to 408 mm).

Adult Specific Characters

Idiacanthus fasciola is distinguished from the other four probably valid species in the genus by the following combination of characters, found only in the adult female: pelvics below first to

eighth dorsal ray, their distance from anal more than one-half their distance from snout; 15 to 18 photophores from pelvic to anal origin. *Color:* (from fresh specimens). Skin: female, brownish black; male, dark brown. Postorbital: female, pinkish silver; male creamy white. Barbel: (female only) stem dark brown, bulb pigmented with translucent flanges and a pale yellow anterior filament. Serial photophores: female, scarlet to purple, the ventral series gold-capped; male, violet. Caudal organs: female, golden yellow; male, creamy yellow. *Proportions:* Depth in length: female, 19 to 27; male, 18 to 22; head in length: female, 15 to 18; male 8.5 to 10.5; eye in head: female, 5 to 7; male, 3 to 4; origin of anal to caudal base in length of fish: female, 2.5 to 3; in male, 3.6 to 4.1; postorbital in head: female, 40 to 50; male 2 to 3; barbel: (female only) 2 to 2.5 times length of head, the anterior filament with a prominent swelling. *Finray Counts:* Pectoral 0; pelvic (female only) 6; dorsal 54 to 74; anal 38 to 49. *Serial Photophores:* Female: lateral series, O–V 21 to 25, V–A 30 to 36; ventral series, I–V 33 to 36, V–A 30 to 36 (15 to 18 to anal origin); A–C 14 to 18. Male: lateral series, O–A 48 to 55; ventral series, I–A 58 to 65 (54 to 59 before anal origin), A–C 16 to 20. *Miscellaneous Luminous Organs:* Female: Bases of teeth filled with luminous matter; a very small, white, luminous patch below postorbital organ; three longitudinal series of similar patches along body, dying out caudally; a moderate amount of granular luminous material on unpaired fins; a small mass of yellow tissue on the dorsal surface of the caudal peduncle extending out onto the raylets; a similar, but larger body, with a small one distal to it, in the ventral lobe of the caudal fin; first pelvic ray with small, round photophore-like patches. Male: Luminous matter within jaw bones; abundant luminous granular material on unpaired fins; caudal organs similar to female's, but relatively smaller, paler, the more distal organ in the ventral caudal lobe rudimentary or absent.

Development

The 129 specimens of *Idiacanthus fasciola* in the Bermuda collection represent all stages of development from young larvae of 16 mm to mature females and males measuring up to 270 mm and 44 mm in length respectively. The following table shows the relation of these growth stages to standard length, sex and numerical abundance:

		Sex Unknown	Females	Males	Total
Larvae: 16–28 mm		13	—	—	13
Post-larvae: 36–50 mm		—	9	10	19
Adolescents	Females: 43–161 mm Males: 28–40 mm	—	20	17	37
Adults	Females: 190–270 mm Males: 32–44 mm	—	4	56	60
Total		13	33	83	129

In a word, the immature specimens are almost evenly divided between the sexes, but the adult males are 14 times more numerous than the adult females and less than one-sixth as long. When all of the specimens in which sex can be determined are counted, the ratio of males to females is 2½ to 1. Adult males form over two-fifths of the entire collection.

In development *Idiacanthus* is typically Stomiatoid except for the stalked eyes of the larvae and the degenerate, post-larvoid form of the males. The latter throughout life lack teeth, pelvic fins and barbel, but develop enormous postorbital light organs and are sexually highly precocious, to mention only the most obvious of their peculiarities. Therefore the criteria ordinarily used in referring young Stomiatoids to particular growth stages, although perfectly applicable to the female, are of little value in the case of the male. Nevertheless there is a complete series composed of several well defined stages which are as logically the post-larval, adolescent and transitional forms of the male as are corresponding degrees of development in the female. As far as appearances are concerned (omitting sexual characters which make even adult males resemble post-larvae in many respects), the growth stages of the two sexes are correlated as follows:

Female		Male
Larvae (sex indeterminable)		
Post-larvae	=	Post-larvae
Transitional Post-larvae	=	Adolescents
Adolescents	=	Transitional Adolescents
—		Adults
Transitional Adolescents		—
Adults		—

In the following summary of the characteristics of the growth stages, both the Stomiatoid affinities of the fish and the specializations mentioned above are apparent: The larva is characterized by a pendulous gut with protruding end, a slender body, large head, large eyes at the end of long stalks, long flat snout, small mouth, larval denticles, rudimentary fins with strong pectoral pad, and a lack both of general body pigment and of light organs; this is a period of growth.

In the post-larva the eye-stalks are gradually absorbed while fins and light organs are forming, the head, eye and snout reduced and the gape enlarged. Sex is now determinable as the barbel and pelvics of the female are distinguishable while the postorbital organs of the male are already enlarged and the gonads slightly swollen. There is however, no appreciable difference in size between post-larvae of corresponding stages but different sexes. These young fish are long compared with the majority of Stomiatoids, unmetamorphosed *Idiacanthus* post-larvae reaching a length of 50 mm. There seems to be little or no growth during this stage. Shrinkage, accompanied by increased depth, takes place in both sexes during the later post-larval and early adolescent periods, slight in the case of the female (7 mm or less), great in that of the male (possibly up to 20 mm).

During adolescence in both sexes all traces of eye-stalks and pectoral fins vanish, pigment appears and the gape increases enormously (though to a greater extent in the female than in the male), but here the parallelism ceases. The female, exactly as in related forms, slowly develops teeth, barbel, bone and stomach; the skin blackens; head, eye and snout become further reduced and the postorbital organ minute; and a long transitional adolescence of actual growth is passed through before the gonads become at all enlarged and sexual maturity attained. In contrast, the male passes quickly through adolescence to adult-hood, always a stage ahead of the female, having few changes to make in its organization. The postorbital organ becomes enormous, the gonads swell to great proportions, and an external copulatory organ is formed, supported by the specialized first rays of the anal fin—these are the only positive developments made subsequent to metamorphosis. The other characters are static or degenerate, as the skin remains relatively light, the head and eye large, the snout long, the mouth edentulous, pelvic fins and barbel absent and the skeleton almost or entirely

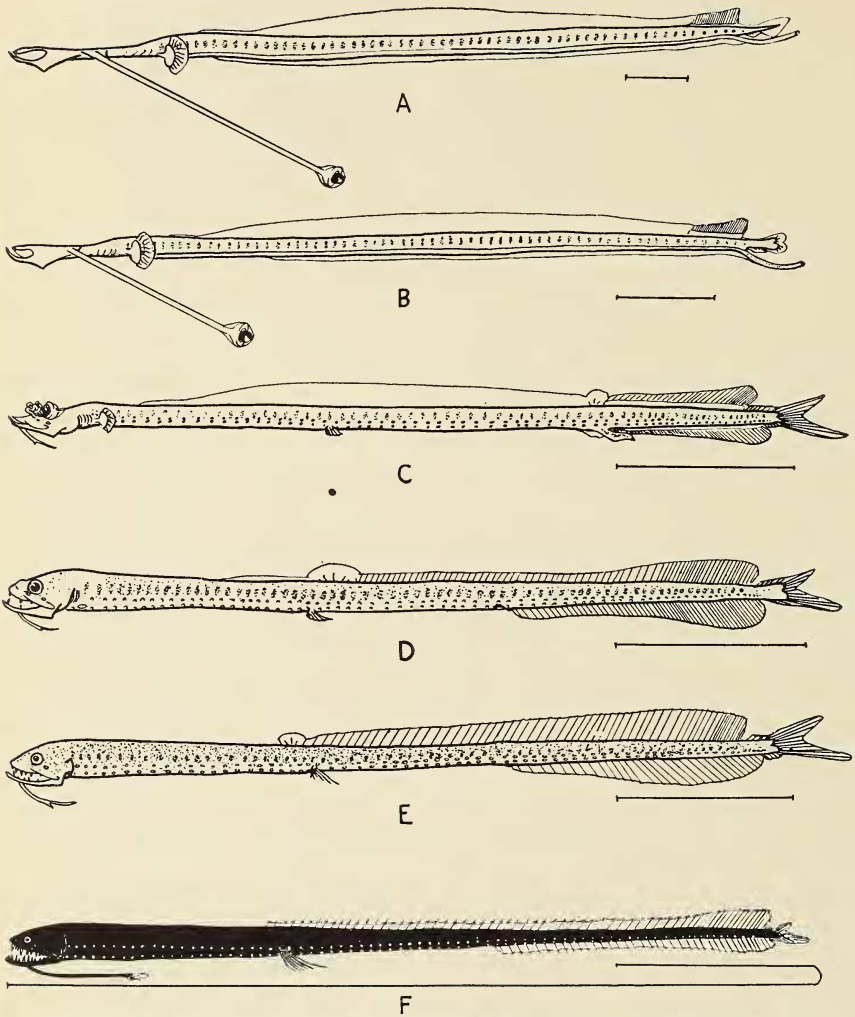


Fig. 49. Growth stages of female: A and B, sexually indeterminable larvae, 16 mm. and 25 mm., respectively; C, female post-larva, 45 mm; D, female transitional post-larva, 48 mm; E, female adolescent, 45 mm; F, female adult, 267 mm. The relative size of the specimens is indicated by the straight lines.

cartilaginous, while the digestive system atrophies and becomes completely useless. As is to be expected, there is no increase in length.

Detailed descriptions of each growth stage are given below.

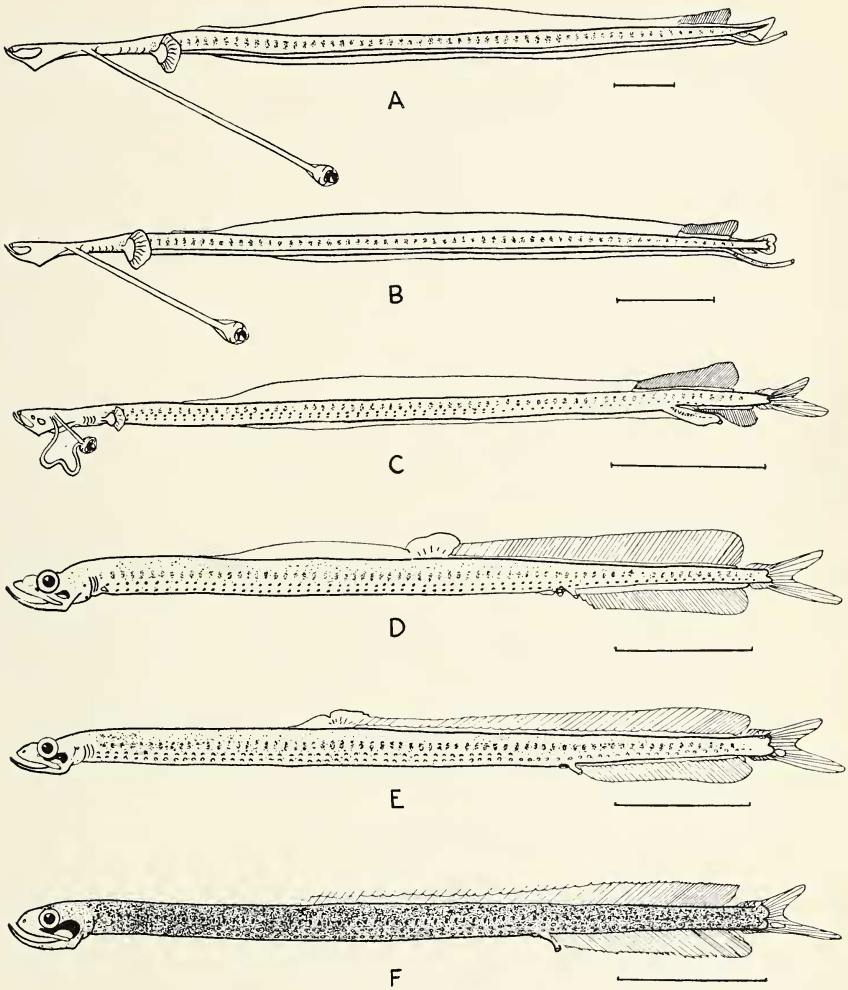


Fig. 50. Growth stages of male: A and B, sexually indeterminable larvae, 16 mm and 25 mm, respectively; C, male post-larva, 40 mm; D, male adolescent, 35 mm; E, male transitional adolescent, 35 mm; F, male adult, 38 mm. The relative size of the specimens is indicated by the straight lines. For ease in comparison the larvae of Fig. 49 (A and B) are reproduced in this figure also.

Eggs: The single breeding female (standard length 267 mm) of the collection contained a total of about 14,000 fully developed eggs. The transparent, minutely dimpled, egg membranes measure between .5 and .6 mm in diameter, the yolks between .4 and .45 mm.

In the majority of eggs one large and from two to eight small oil globules are clearly visible. Undeveloped, very minute eggs are present in small numbers between the fully developed ones, but there are no intermediate sizes. The eggs in the anterior part of each ovary are full size, but much paler in color (white, whereas the rest have deep yellow yolks in preservative) and almost opaque, with no distinction between yolk and outer membrane and no sign of oil globules.

In the other three mature females (190 to 270 mm) the eggs are graduated in size, instead of being of two sizes only, and the largest are only one-third to one-half as big as in the breeding

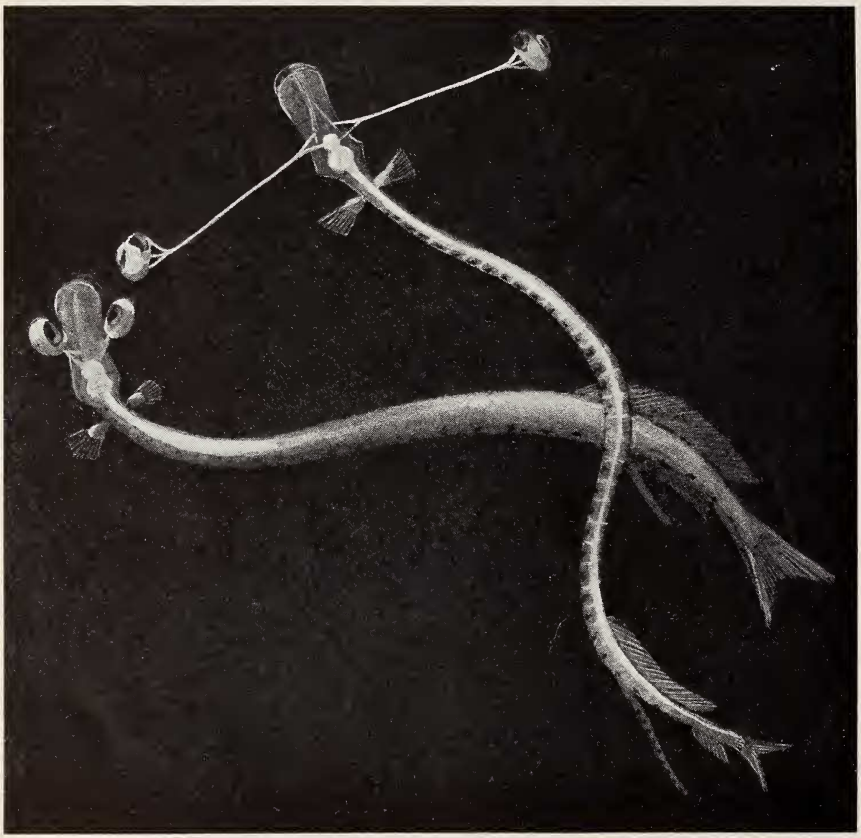


Fig. 51. Stalk-eyed larva and post-larva. (From a painting by Else Bostelmann).

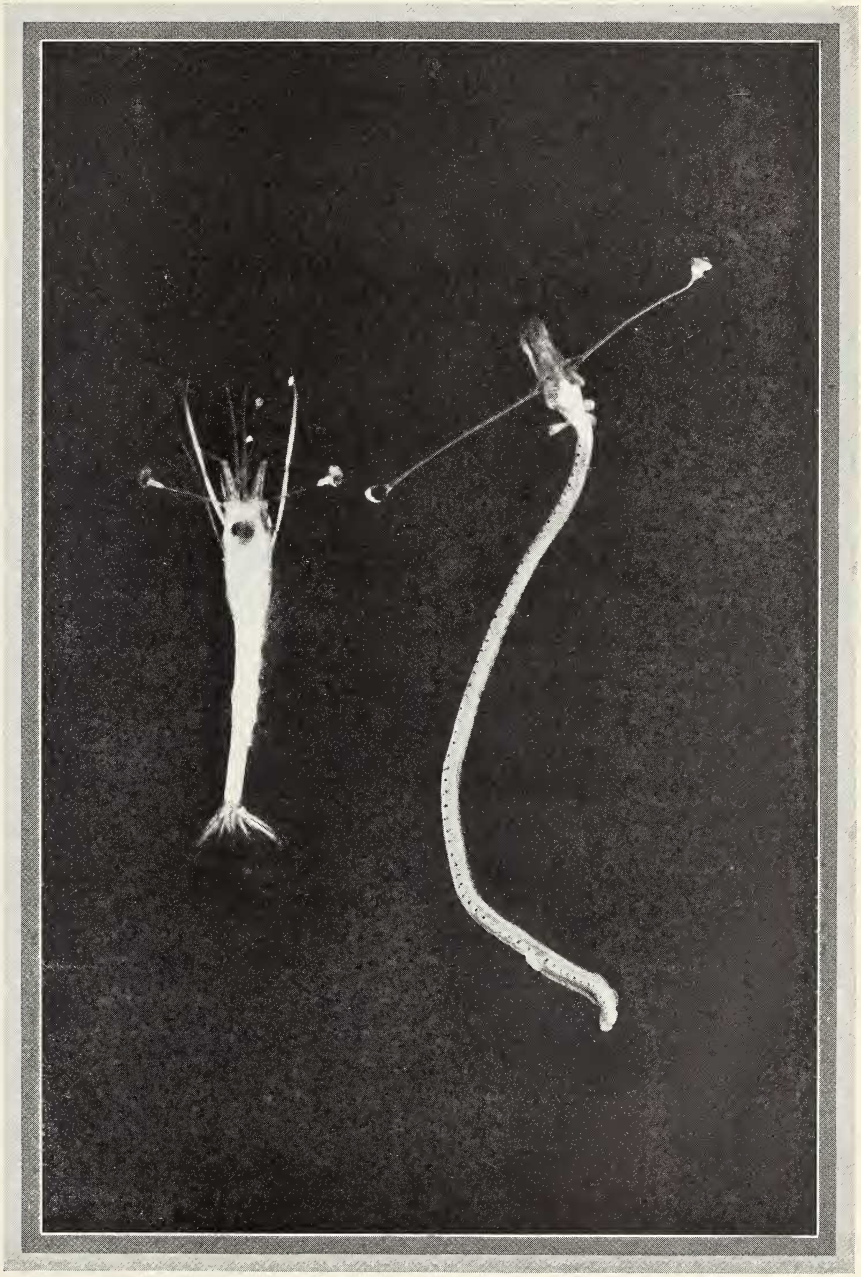


Fig. 52. Stalk-eyed larva photographed beside young deep-sea shrimp (*Sergestes* sp.), showing the presence of stalked eyes in wholly unrelated phyla.

specimens (.2 to .3 mm in diameter). Similarly, the ovaries are only one-fourth to one-third as broad and are very flat.

Among the transitional adolescent females (48 to 161 mm) the largest eggs of each measure from less than .01 mm to .06 mm in diameter, while the ovaries are slender ribbons, .6 mm broad in the longest specimen, mere strings in the small examples, and all divided from their mates on the opposite side of the dorsal mid-line by a considerable space. In all except the largest specimens—that is, in all fish 125 mm long or less—the eggs are individually very feebly developed, translucent and jelly-like.

Eggs of adolescent fish are individually indiscernible.

LARVA: The 13 larvae, measuring from 16 to 28 mm in standard length, differ little from one another in appearance and proportions. The one great difference is in the size of the liver, which is relatively about three times as large in the largest specimens as in the smallest. On the other hand, the eye-stalks are almost as long in actual measurement in the shortest larvae as in the longest, so that in this character there is a relative reduction in stalk length, although throughout the stage the eye-balls remain firmly fixed at the extreme tips of the stalks. I agree with Taaning's suggestion (1932, p. 272) that Brauer's youngest, short-stalked specimens were probably young *Bathylagus*, as very similar Bermuda specimens proved to belong to this genus.

Larval Trawling Data: The description given below is verified and supplemented as usual by study of all of the larvae in the collection, both uncleared and cleared, but the actual measurements are taken from the following specimen: Department of Tropical Research No. 23,545a; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1308; September 16, 1931; 7 miles south of Nonsuch Island, Bermuda; 100 fathoms; Standard length 16 mm.

Larval Measurements and Counts: Standard length 16 mm; depth .43 (in length 37.2); head 3 (in length 5.3); eye diameter, horizontal, .2 (in head 15, in length 80); eye diameter, vertical, .54 (in head 5.6); base of stalk to tip of lens 6 (in length 2.7); snout 1.4 (in head 2.1, in length 11.4); maxillary .8 (in head 3.7, in length 20) dorsal origin to caudal base 1.9 (in length 8.4); dorsal rays 24; anal ray bases 10; projecting, terminal portion of gut 1.4.

Larval External Characters: (Figs. 49A, B; 50A, B; 51; 52; 53A,

A′). There are about 64 mid-lateral blotches from the gill-slit almost to the caudal base, one in the middle of each myomere. In addition, 6 much smaller spots are found along the mid-line of the isthmus. The rest of the larva is entirely unpigmented and almost transparent, especially in the cephalic region.

In general form this young fish is even more elongate than the adult, and of a nearly constant calibre as far back as the dorsal origin. From here the body tapers abruptly to its pointed tip, the caudal peduncle being exceedingly short. The head is large, somewhat under a fifth of the standard length, and much flattened. The snout is broad, fully half the length of the head, and perfectly horizontal. The jaws are typical of Stomiatoid larvae, the premaxillary a minute sliver of cartilage, the maxillary reaching halfway to the base of the eye-stalk, at about the same vertical as the prominent mandibular angle. The nostrils are located far forward, close behind the premaxillary but well separated from each other by the mesethmoid cartilage.

The structure of the eyes and stalks agrees well with Brauer's description of the long-stalked stage of *Stylophthalmus* (1908, p. 179 ff.). The principal elements of the stalk are cartilaginous rod and the optic nerve. The first is an outgrowth of the cartilage of both the future frontal bone and of the parasphenoid, and runs the full length of the stalk on its anterior side, disappearing into the outer membranes of the eye-ball. The second element, the optic nerve, arises from the forebrain and runs along the posterior side of the stalk. Both cartilage and nerve, as well as the various small muscles, tactile nerves and blood vessels, are enclosed in a common, transparent sheath which extends completely around the eye itself, protecting the lens just as in older fish. The eye-ball is located at the extreme tip of the stalk, the major portion of the round lens projecting beyond the shallow, elliptical, thick-lipped saucer of the eye-ball proper.

Both jaws contain fine denticles of a typically larval Stomiatoid character: these are directed straight outwards in the premaxillary and mandible, and downwards in the maxillary. The numbers are as follows: premaxillary 7; maxillary 13, increasing slightly in size posteriorly and with larger spaces between them; mandible 7, similarly increasing in size, but present in the anterior part of that jaw only.

The gill slits are wide open, with no trace of operculum.

The pectoral fins are relatively very large, the great fleshy pads resting on sturdy columns and fringed deeply with raylets. The following measurements were taken: maximum length of fin, from origin of base to tip of raylets, .7 mm; maximum expanse of base .43 mm. There is no trace of pelvics. The dorsal is far back, occupying only the posterior six per cent of the body, the rays short, close-set, with prominent bases. The anal is rudimentary, located behind the end of the dorsal, with no true rays apparent, although the bases of about ten are distinguishable. These arise toward the middle of the low finfold which runs from the exit of the intestine to the caudal fin. The latter has no true rays, is pointed, and extends little beyond the urostyle, with the ventral portion more developed than the dorsal.

There are both dorsal and ventral finfolds along the profiles from nape to caudal. These are deepest dorsally behind mid-body where the fold considerably exceeds the maximum body depth. The entire ventral finfold, however, is very shallow.

Larval Osteology: The skeleton is completely unossified. In the fresh and preserved specimens the head is so transparent that details of the cartilaginous elements can be studied more easily than in artificially cleared examples.

Larval skull: (Fig. 58). The top of the skull forms roughly an elongate rectangle with the eye-stalks arising about half-way between the snout and the posterior end of the supraoccipital. The cartilaginous areas, while very distinct, are exceedingly homogeneous as regards division into future elements. At the anterior end of the upper jaw the mesethmoids, in some individuals, are set off by extremely faint lines of demarcation. Behind them the frontals join down the center but show in that region a narrow, clear area between very low ridges. Posteriorly, in older larvae, they can be traced over about half of the outer lobe of the brain. The width of the skull from eye-stalk forward is doubled by rigid lateral membrane. The supraoccipital is very large, covering the entire brain and midway of its length expanding into large, rounded, lateral wings. Outside the widest of these expansions we find the rather indefinite sphenotic characterized even at this stage by a lateral projection. Posterior to this is the pterotic, which curves decidedly inward toward the mid-line. The elongate, oval epiotic follows, projecting

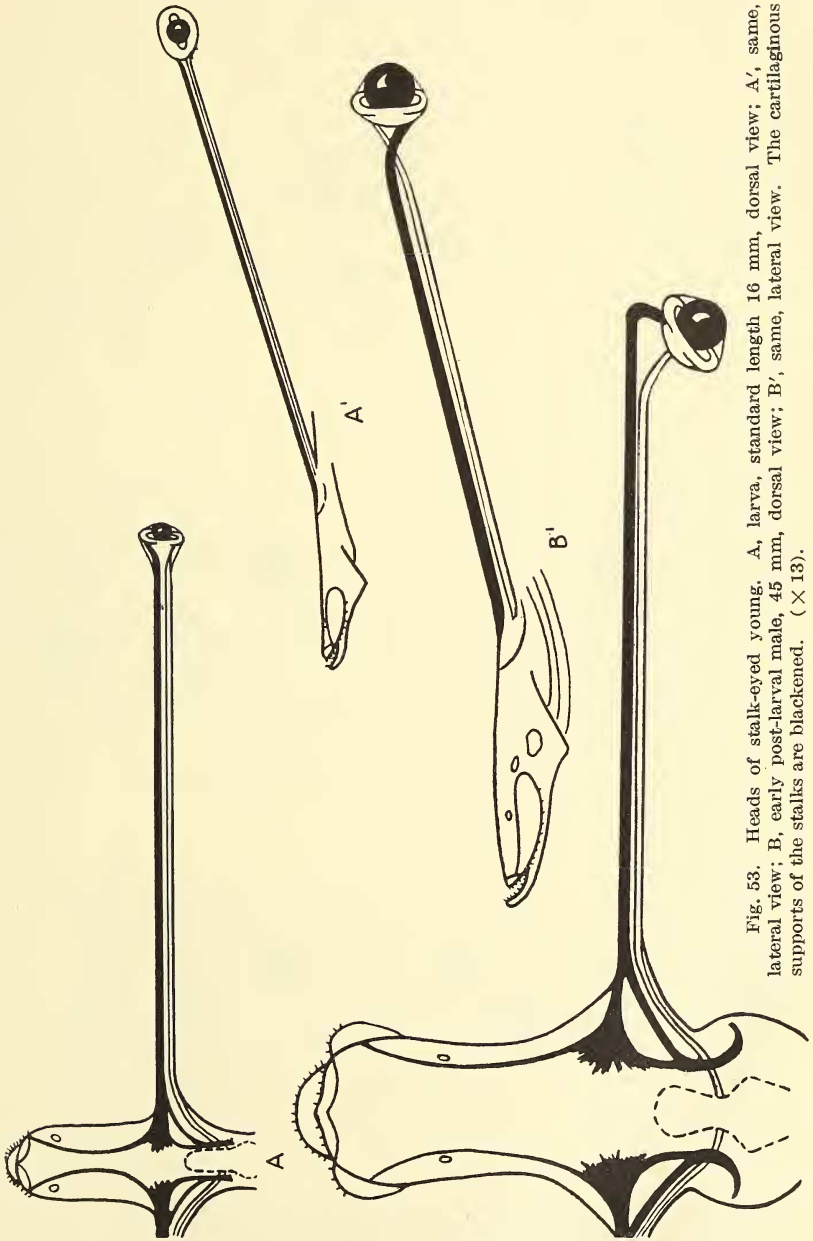


Fig. 53. Heads of stalk-eyed young. A, larva, standard length 16 mm, dorsal view; A', same, lateral view; B, early post-larval male, 45 mm, dorsal view; B', same, lateral view. The cartilaginous supports of the stalks are blackened. ($\times$ 13).

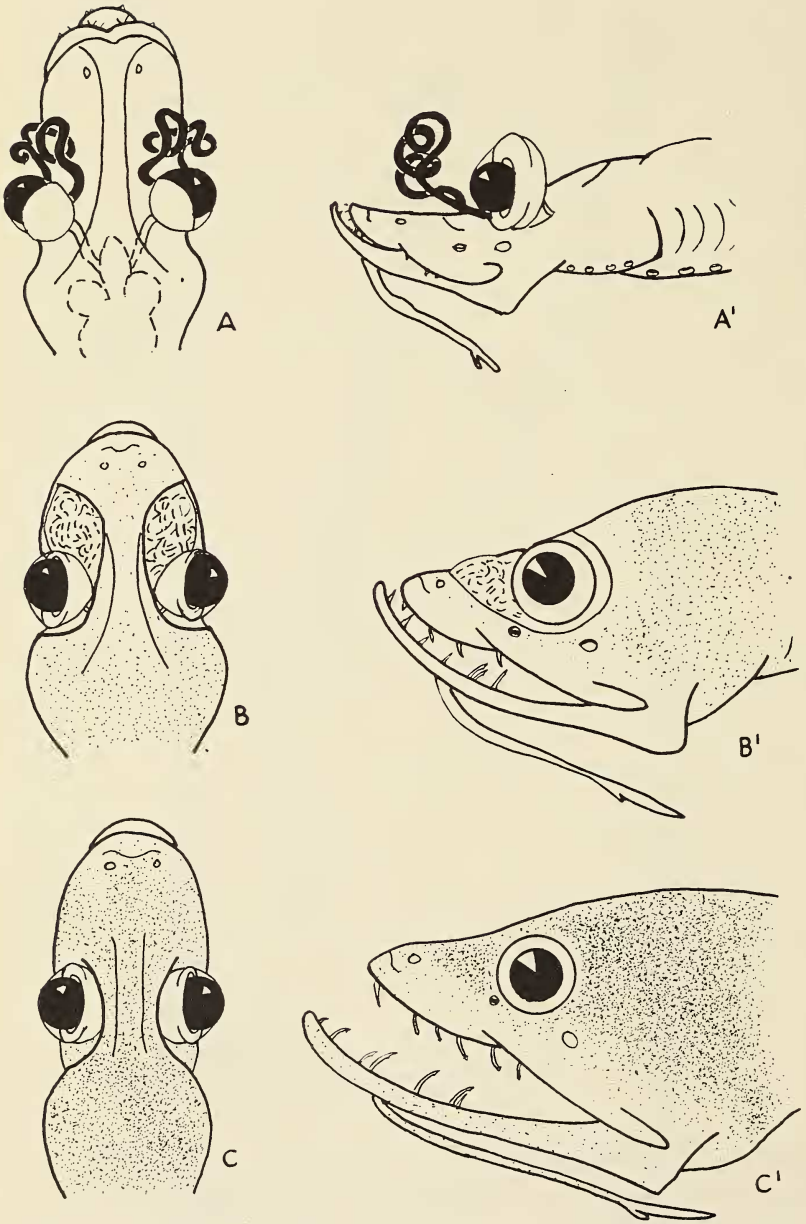


Fig. 54. Heads of young females. A, post-larva, standard length 45 mm, dorsal view; A′, same, lateral view; B, transitional post-larva, 48 mm, dorsal view; B′, same, lateral view; C, adolescent, 43 mm, dorsal view; C′, same, lateral view. (× 13).

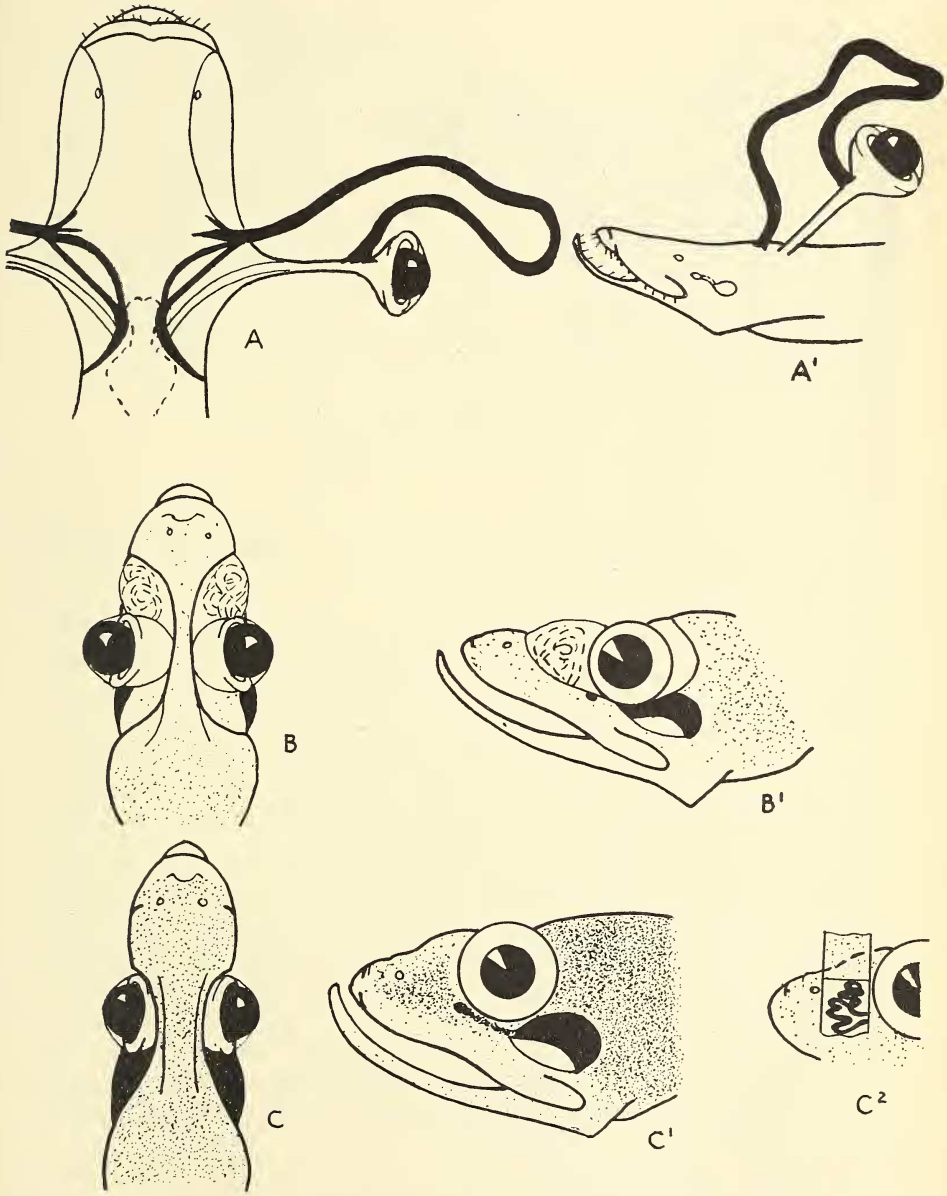


Fig 55. Heads of young males. A, post-larva, standard length 40 mm, dorsal view; A′, same, lateral view; B, adolescent, 35 mm, dorsal view; B′, same, lateral view; C, transitional adolescent, 35 mm, dorsal view; C′, same, lateral view; C², same, with flap of skin lifted to expose eye-stalk coiled behind nostril. (× 13).

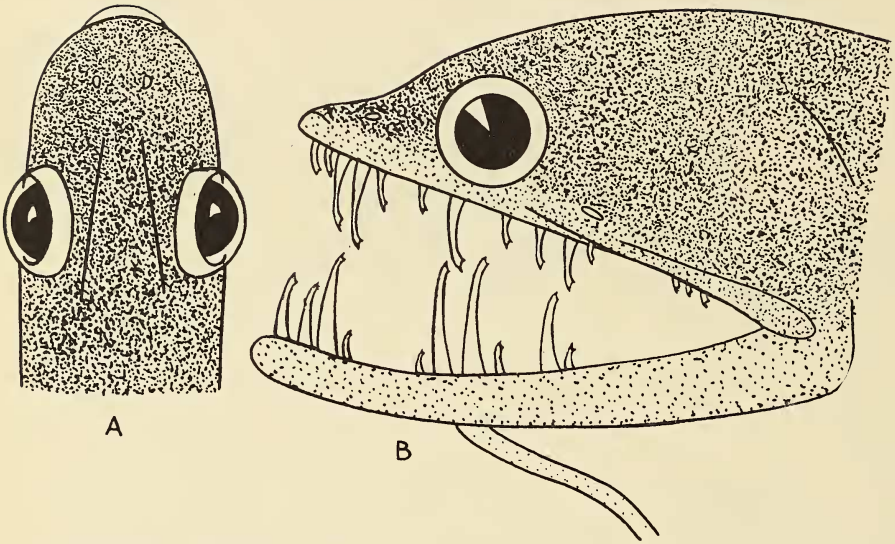


Fig. 56. Head of female transitional adolescent, standard length 75 mm. A, dorsal view; B, lateral view. (× 13).

backwards well beyond the supraoccipital. In the roof of the mouth the parasphenoid appears to be represented by a low median ridge which posteriorly expands and forms the base of the brain.

At about the middle of the length of the skull the frontals above and the parasphenoid below unite into large, solid, lateral projections which support the main rods of the long eye-stalks already described. The elements of the projections are flattened along their extended base, but almost immediately contract at each side into a cylindrical rod. Just beyond the limits of the skull the actual cartilage of the rod gives place to a striated tissue, apparently muscular, but after a very short distance cartilage reappears and continues unbroken throughout the eye-stalk. This short, altered area doubtless affords the requisite pliability, allowing the strong, basal muscles to draw the eye-stalks forward and back. A second, smaller, cartilaginous rod arises near the meeting of the parasphenoid and the anterior end of the supraoccipital and enters the stalk just posterior to the larger anterior rod.

Larval palato-pterygoid arcade: (Fig. 59). Even in detailed delineation the lateral view of the head presents an appearance of diagrammatic simplicity, the bones of the head and the branchial

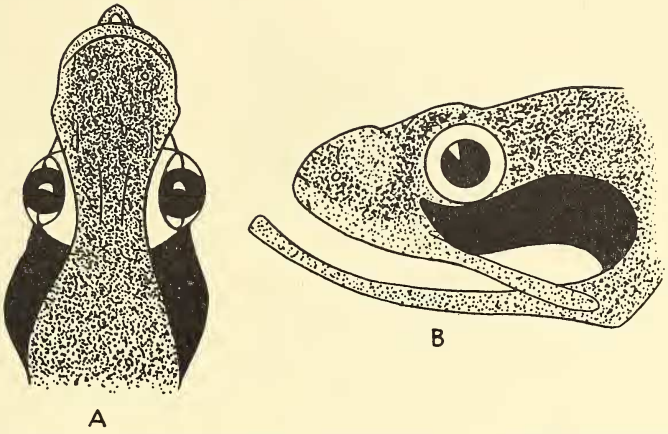


Fig. 57. Head of adult male, standard length 38 mm. A, dorsal view; B, lateral view. (× 13).

arches being almost all of simple, rod-like, elongate character. The hyomandibular shows at its upper end a knob-like articulation with the pterotic. From here it extends forward, narrowing rapidly while at the same time its superior width is maintained by the appearance and increasing width of the quadrate. Directly above the quadrate and parallel with it is the long, narrow pterygoid. Its posterior end disappears in the surrounding tissue while anteriorly it is loosely connected with the palatine.

Larval jaw apparatus: (Figs. 59, 60). The primary upper jaw consists of a short premaxillary lacking the dorsal prolongation found in the adult and attached to the extremely long, straight maxillary which widens gradually toward its proximal articulation. The supramaxillary is distinct and contained within the even curve of its outline. The lower jaw shows a slight upward curve in its distal third and widens considerably at its attachment to the quadrate, showing a deep bay for articulation with the head of the latter bone.

Larval opercular bones: (Fig. 59). The only hint of the opercular apparatus is a slender, needle-like, cartilaginous bar extending close beneath the hyomandibular and dying out about half way down the quadrate.

Larval hyoid apparatus: (Fig. 59). The glossohyal is relatively large, broadly shield-shaped as seen from above, deeply incised on its anterior profile and about one-third as long as the entire lower jaw.

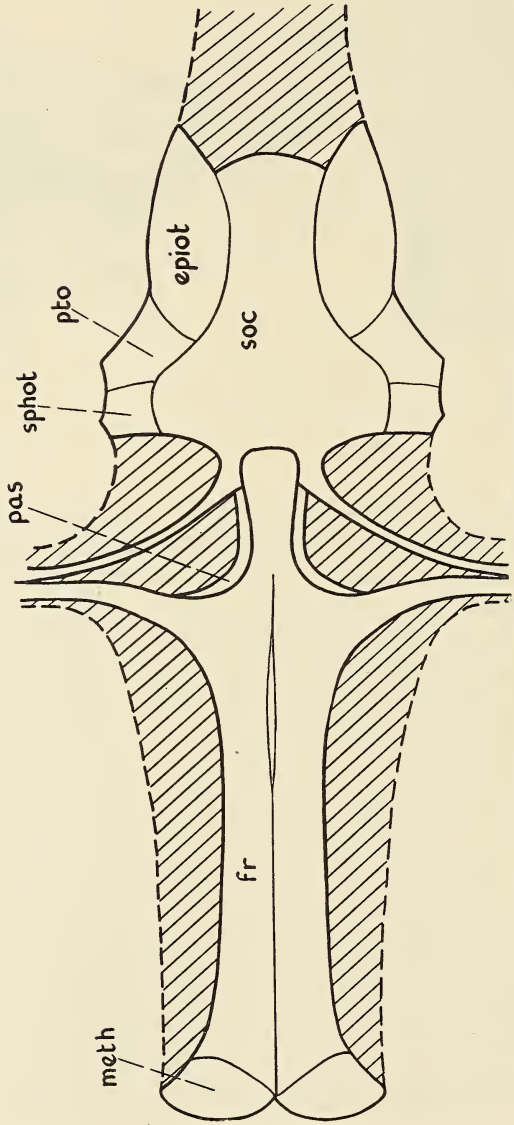


Fig. 58. Cartilaginous elements of larval skull, dorsal view. (× 40).

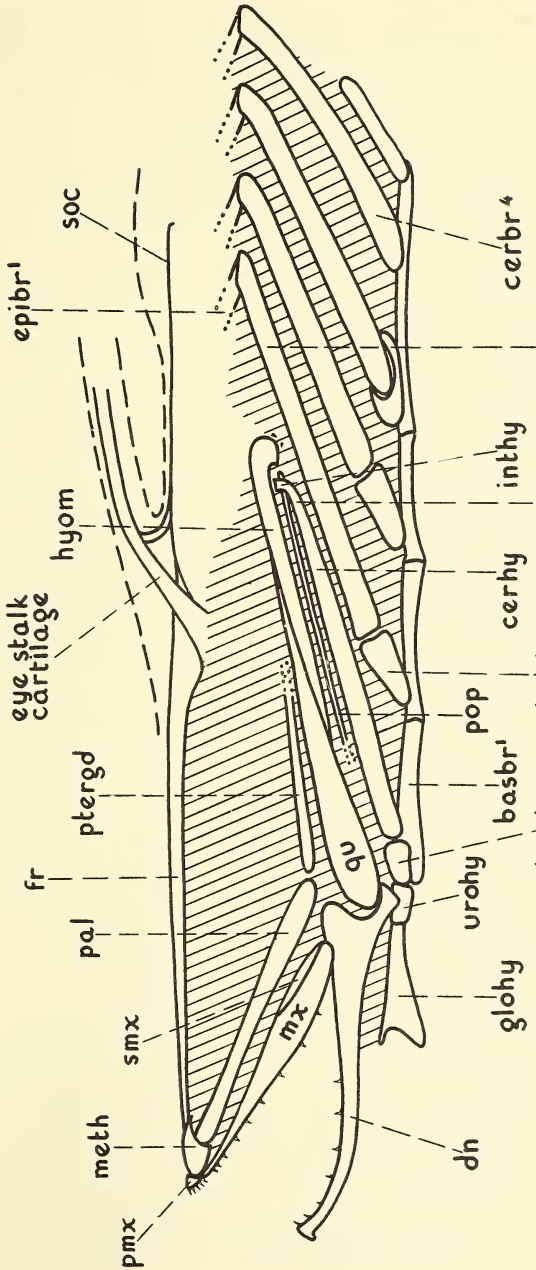


Fig. 59. Cartilaginous elements of larval head, lateral view. The basibranchials have been pulled down to bring into view the hyoid and branchial apparatus. Normally the entire head is greatly flattened dorso-ventrally. (× 40).

Directly behind it is a small, roughly square urohyal. The basihyal is about the same size and shape as the urohyal, and is succeeded by a long, stout ceratohyal longer than the entire lower jaw. The superior end of the ceratohyal is curved upward and while it doubtless contains the elements of the epihyal and interhyal, the latter are as yet undifferentiated from the substance of the cartilage.

Larval branchial apparatus: (Fig. 59). Four basibranchials are sharply demarcated, the fourth one twice as long as the others and giving rise to the third, fourth and fifth branchial arches. The first, second, third and fourth arches are very similar in general appearance, and the first and second hypobranchials identical in size and shape. The third hypobranchial, while of the same size as the others, is already somewhat differentiated, exactly as in adult fish: Instead of being attached to the ceratobranchial by one end, a rounded, sunken articulation with that bone is shown. The fourth and fifth ceratobranchials lack the basal element, the fifth being less than one-half as long as the fourth and shows no further elements at its superior end. The first, second, third and fourth epibranchials are visible only as short bits of cartilage which soon die out in the surrounding tissue. There is no trace whatever of pharyngeals.

Viewed as a whole the lateral aspect of the head of the larva presents a startlingly apparent—although purely adventitious—indication of the elements of ten successive arches: the true jaws, the palato-pterygoid, the quadrato-hyomandibular, the preopercular, the hyoid, and the five true branchial arches. This false appearance is brought about by the close similarity in shape, size and angle of the ten structures and is of course completely lost during the development into the post-larval stages.

Larval pectoral and pelvic girdles: The elements of neither of the fin girdles are distinguishable.

Larval vertebral column: (Fig. 61A, a). The vertebrae are almost cylindrical and the individual centra are not always clearly to be distinguished from their neighbors. In a larva of about 20 mm in length a vertebra from the center of the body measured .27 mm in both length and maximum diameter. There is a decided decrease in size toward the base of the caudal fin. No appendages are discernible.

Larval Digestive System: (Figs. 62A, B; 63A, B; 64A, B; 65A, B).

The alimentary canal is 82 per cent as long as the fish. Behind the pectoral or cardiac region the gut is but partially enclosed in the body cavity, the ventral half supported only by the most delicate of membranes and forming a bulge along the abdominal surface. Beneath the dorsal fin, the gut emerges entirely, swells to twice its anterior diameter, and for the posterior one-tenth of its length is completely external, projecting backwards well beyond the end of the caudal fin. This exterior part is closely applied to the ventral portions of the body and caudal fin. It is attached intimately to the body behind the dorsal by a narrow membranous area, and again posteriorly to the base of the caudal fin. Between these points however it is free, and it is here that the rudiments of the anal fin are appearing.

The oesophagus is 1.4 mm long by .06 mm average breadth and extends to the tenth myomere. The anterior third lies in the midst of the body, above the heart, but behind this begins the pendulous portion noted above. Its middle part shows a valvular construction, composed of several swellings alternating with constrictions. The rudimentary liver, which is a small mass of granular substance .3 mm in length, curls upward close against the posterior fifth of the oesophagus, from the eighth to the ninth myomeres. At the tenth myomere the anlage of the stomach is visible, a minute white papilla about as broad as long (.05 mm) arising from the left side of the gut. There is no trace of caeca in the short, slightly constricted pyloric region which, to the right of the stomach, connects the oesophagus with the intestine. From the small swelling at the anterior tip of the intestine a long and thread-like bile duct (.85 mm) joins the gut with the posterior tip of the gall bladder. The latter is about as long as the liver and lies far in front of it, immediately behind the heart. Connections between liver and bladder are not found. There is no trace either of pancreas or spleen. From the pyloric region the gut, always slightly broader than the oesophagus and increasing in diameter posteriorly (from .07 mm in the middle portion to .14 mm in the protruding end) extends straight backwards until it leaves the body at a broadly obtuse angle.

Larval Reproductive System: Neither gonads nor external genitalia are visible.

Post-Larva: During the post-larval stage the optic nerve in the eye-stalk, with its accessory nerve and muscle fibers, is gradually absorbed, pulling with it the eye-ball. Under the strain the carti-

laginous rod, no part of which is absorbed at this time, rips out from the common sheath of the stalk and, still firmly attached both to the base of the eye-ball and to the frontal cartilage, bows over and gradually coils down into the open front of the eye-socket, well behind the nares. Although no change is visible from gross examination, yet the cartilaginous eye-stalk—stiff and resilient when functioning—must undergo some internal tissue alteration to become pliable enough to coil down and into its final grave in the anterior part of the cranial eye-socket. This spiral is neither covered with epidermis nor absorbed, until adolescence. In the youngest of the post-larvae, a male, the optic nerve is but slightly shrunken and consequently the distal end alone of the cartilage is affected, bending backwards at a right angle (Fig. 53B, B′). Partially formed serial organs are faintly visible in this specimen and the masculine post-larval characters (p. 159) developed in proportion. A somewhat older male is described in the pages following: The female treated immediately below, although the youngest post-larva of that sex in the collection, is still older, but because it is of the unspecialized sex it is described in advance of the male of the corresponding stage.

Post-larval Female Trawling Data: All of the characters except those of the skeleton are based upon the following specimen: Department of Tropical Research No. 23,941; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1337; October 29, 1931; 9 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 45 mm.

Post-larval Female Measurements and Counts: Total length 48.5 mm; standard length 45 mm; depth 1.4 (in length 32.1); head 4.3 (in length 10.5); eye, horizontal, .8 (in head 5.4, in length 55.5); eye, vertical, 1.3; snout, to cartilage, 1.4 (in head 3.1, in length 32.1); snout, to iris, 1.8 (in head 2.4, in length 25); snout to pelvic 18.5 (in length 2.4); dorsal origin to caudal base 10.1 (in length 4.5); anal origin to caudal base 9.3 (in length 4.8); pectoral length 1.1; pelvic rays 6; pelvic length .7; dorsal rays 64; anal rays 45; post-orbital .2 (in head 21.5, in length 225); barbel 2.2 (in head 2); branchiostegal organs 14; serial photophores: lateral series, O–V 23, V–A 32; ventral series, I–V 34, V–A 32, A–C 17.

Post-larval Female External Characters: (Figs. 49C, 54A, A′). General pigment is practically absent, although there is an exceedingly fine dusting of microscopic brown specks. There are 72

blotches along each side and 7 small spots in the mid-line of the isthmus, while the protruding tip of the gut is laterally and distally pigmented.

The body is of typically Stomiatoid post-larval form, relatively deeper than in the larva, with the highest point toward mid-length and the caudal region much thicker than in the adult female. In other proportions too the post-larva is a perfect intermediate form: the caudal peduncle is mid-way between the minute tail of the larva and the long one of the adult, while head and snout, though much reduced compared with their early proportions, are still much longer than in the mature fish.

The maxillary reaches the eye proper (i. e. behind the cartilaginous stalk) and the mandibular angle falls at the vertical from the middle of the eye. Due to the nearly complete absorbtion of the external portion of the optic nerve the eyes are drawn close to the head, although they are loose in their large sockets. In the anterior parts of these cavities, between the nostrils and the eyes, the cartilaginous stalks are coiling down into their final positions before dissolution, each stalk forming a series of four or five loose kinks which are still completely external, above the level of the snout. The proximal and distal ends are as yet firmly attached to the skull and eye-balls respectively. The eyes themselves are still vertically elongate, directed obliquely forward.

Traces of larval denticles are found in the premaxillary only; on the other hand there are two or three rudimentary, exceedingly short, true teeth in each jaw.

The opercles are very short, covering only the most anterior of the gill arches.

The pectorals are still large (over a millimetre in length from base to tip of raylets) and fully formed. The tiny pelvics have all of the rays clearly distinguishable. The dorsal has only a third the relative extent of the adult, although all of the rays are formed and the anterior ones already have considerable spaces between them. The anal also has the full number of rays; it occupies three-fifths as much space as in the adult and commences slightly behind the dorsal origin. Its more anterior rays are exceedingly short; their development seems to have been retarded by the backward extension of the gut in earlier stages, which shows its effect even at this point, when the intestinal tip alone remains external. Both fins have firm, con-

tinuous bases which are easily detached from the surrounding skin with the rays intact; these are undoubtedly connected with the tremendous forward migration of all but the most posterior finrays. The lateral spines of dorsal and anal are discussed in connection with the osteology. The caudal fin is now of adult form—bilobed, with the lower half the longer and all of the rays strongly developed. The fin is contained about 13 times in the standard length, as opposed to some 33 times in the adult female.

Traces of finfold are present ventrally, but the only conspicuous fold lies along the middle of the dorsal profile; here it is about equal in height to the maximum depth of the fish.

The antorbital organ although small is a perfectly formed, obviously functional, double-centered photophore, pointing both down and up as usual among Stomiatoids, at least in the young; it is placed directly beneath the anterior attachment of the cartilage stalk. The postorbital lies beneath the middle of the eye itself, above the mandibular angle. In both organs the pigmented sheath is well developed, although less so in the postorbital. In maximum length the latter is scarcely greater than the antorbital; actually it is half as large as in the mature 267 mm female subsequently to be described, but relatively it is three times larger. Subdermally a slender strand connects the two post-larval organs. The short barbel is perfectly white with a short, thick stem and the component parts of the complex bulb of the future very roughly blocked out; all is quite opaque, with none of the translucency of the delicate flanges of the adult. The opercular, branchiostegal and serial photophores are all completely developed. The caudal lights are indicated, though indistinctly. Luminous granules are present in small quantities on the unpaired fins, but there is no trace of jaw luminescence or of lesser body photophores.

Post-larval Female Osteology: (Fig. 61B). There is no trace of ossification in cleared and stained post-larvae. In conformation the elements of the skull and vertebral column are, as is to be expected, less than half-way between those of larvae and adult females.

Post-larval Female Digestive System: (Figs. 62C, 64C). The gut still bulges ventrally, although it is completely covered by true abdominal epidermis. The tip of the intestine alone projects, lying close beneath the first, short, still repressed, anal rays; this portion is swollen slightly, as in the larva. Due to the elongation of the

caudal peduncle since the larval stage, the gut is now only 70 percent of the standard length. The intestine is broader than the oesophagus as in the larva; in the adult female the reverse is true. The tiny stomach, however, is already wider than either oesophagus or intestine, just as in mature fish.

The oesophagus is straight and unconstricted, 4.8 mm in length, relatively a little longer than in the larva. The organs of the pyloric region differ from those of the late larva (with the large liver) in the following respects: The stomach is much longer (2 mm, in standard length 22.5), of characteristic elongate shape and rather a continuation than an appendage of the oesophagus; in all probability, however, it is not yet functional. A pyloric arm now definitely joins stomach and intestine. From this two very short (.2 mm) but characteristically shaped caeca protrude. The bile duct (.6 mm) is not only relatively but actually much shorter than in either small or large larvae, but the bladder actually and relatively is larger (over a millimetre in maximum diameter). The small, oval spleen (.2 mm) is visible against the anterior end of the intestine, immediately above the bile duct. The liver (1.6 mm in length) although comparatively a little smaller than in the larger larvae, is broader, enclosing all except the most dorsal side of the oesophagus. Its most posterior tip, on the left as always in this species, barely reaches the origin of the stomach, as in females of all stages. The pancreas is not visible. There is as yet no pigment in any part of the gut or body cavity.

Post-larval Female Reproductive System: The gonads are minute inconspicuous threads. A gonopore is plainly visible on a small, separate papilla behind the anus.

Post-larval Male Trawling Data: All of the characters except those of the skeleton are based upon from the following specimen: Department of Tropical Research No. 21,802; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1122; August 3, 1931; 12 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 40 mm.

Post-larval Male Measurements and Counts: Total length 43 mm; standard length 40 mm; depth 1.1 (in length 36.4); head 4.3 in length 9.3); eye diameter, lateral, .74 (in head 5.8, in length 52.7); eye diameter, vertical, 1.1; distance from external base of optic nerve to apex of lens 2.9 (in length 13.8); snout 1.9 (in head 2.3, in length 21.1); maxillary 1.3 (in head 3.3); dorsal origin to caudal base

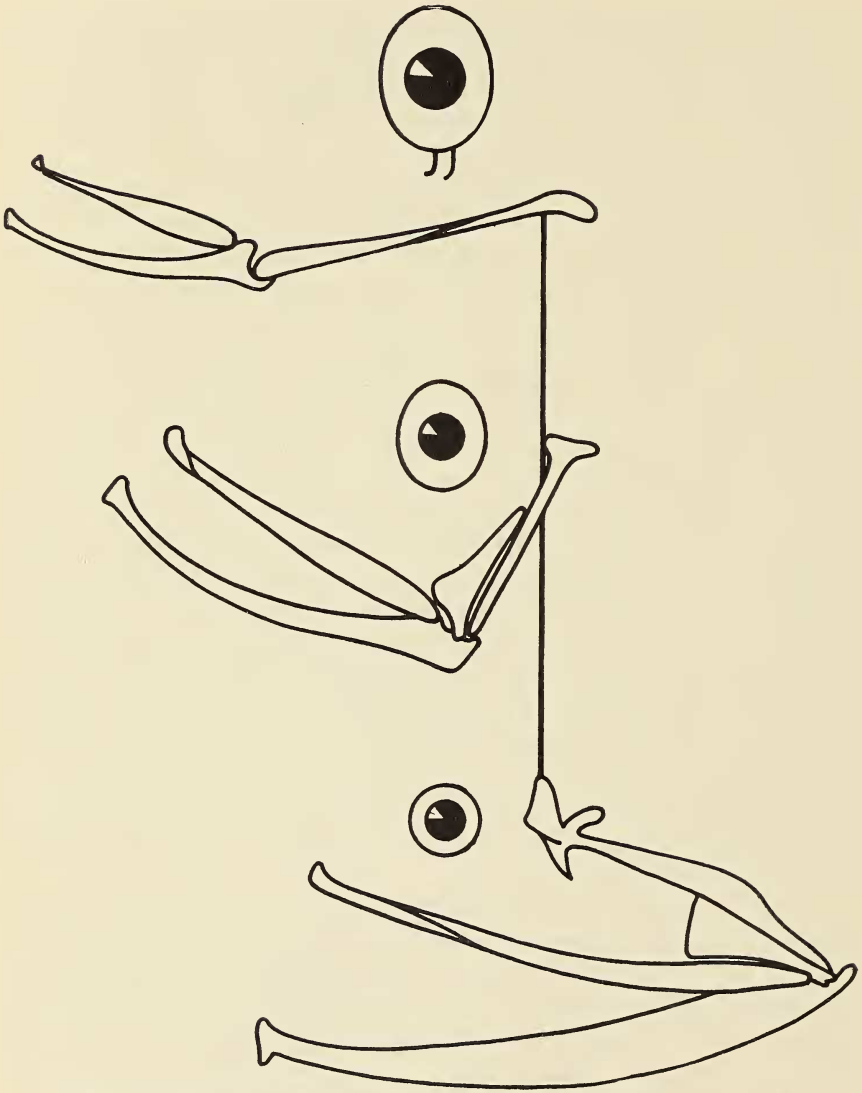


Fig. 60. Diagrams showing change in relative size and position of premaxillary, maxillary, mandible, quadrate and hyomandibular during development. Top figure, larva; middle, post-larva; bottom, adult female. The pivotal point throughout is the junction of the head of the hyomandibular with the pterotic. The eye is shown in exact position and relative size.

7.2 (in length 5.6); anal origin to caudal base 4 (in length 10); dorsal rays 55; anal rays 35; external end of gut 2.3; postorbital .32 (in head 13.4, in length 125); serial photophores: branchiostegals 12 to 13; lateral series 41; ventral series, I–A 70, A–C 0.

Post-larval Male External Characters: (Figs. 50C; 53B, B′; 55A, A′). No general pigment whatever is developed, although the head is less completely transparent and the body more opaque than in the larva. The lateral blotches number 66 in this specimen, and there are the usual half-dozen mid-line spots on the isthmus. On each side of the projecting termination of the intestine closely crowded chromatophores form an almost solid line, and the extreme tip of the intestine is similarly pigmented.

In general form this male post-larva does not differ from the slightly older female except that, as is to be expected, the caudal peduncle is not as long and the head is relatively larger and more larvoid in character, with the dorsal contour still horizontal instead of depressed. As in the female, the arching of the snout has commenced, bringing the jaw bones lower in relation to the eye, although the top of the snout itself is level with the top of the head. The jaws are intermediate between the larval and female post-larval types, the premaxillary still not overlapping the maxillary which extends only two-thirds of the way to the base of the eye-stalk and the mandibular angle falling almost beneath the cartilaginous rod. The nostrils are about midway between the tip of the snout and the base of the stalk, placed laterally.

The eyes are at a most interesting intermediate stage of the stalked phase, as the optic nerve and most of the muscles, tactile nerves and so on have about two-thirds of their former length absorbed, with the eye-ball still firmly attached to their ends, while the anterior, cartilaginous rod has burst completely from the stalk sheath and forms a pendulous loop.

In the premaxillaries and mandible the majority of larval denticles persist (6 in each of the first bones, 8 in each half of the second), but in the maxillaries only several remain in each side, very loose and asymmetrically spaced. There is no trace of true teeth.

The operculum is undeveloped.

The pectorals, although they are actually larger than in the larva, are relatively smaller, but throughout structurally similar, consisting of column, pad and raylets. There is no sign of even

rudimentary pelvics. The dorsal now shows a typically adult number of rays, as in the female, but they are crowded closely together and though occupying relatively two-thirds as much space as in the larva, the base of the fin is only a third as long compared with the standard length as in the adult. The anal has thirty-odd rays well developed, as opposed to the ten rudimentary elements of the larval anal, yet the fin is not adult in either ray number or extent, as, like the dorsal the base occupies less than one-third as much space as in the mature male. In accordance with a well marked sexual character unaffected by age, the fin base is much shorter than in the post-larval female. The caudal fin is well formed with distinct rays, a moderately deep fork, and a ventral lobe slightly longer than the dorsal one; the fin is however shorter than in adult males (contained about 13 times in the standard length as opposed to 8 to 11). In the female the opposite is true, the tail of the young being longer than in the adult.

Finfolds are rudimentary except along the middle of the back, where the fold equals the maximum body depth.

Antorbital and postorbital lights are both distinguishable, though rudimentary and with no pigmented cup. The postorbital is relatively and actually less than a fourth as large as in adult males, but already in both respects it is larger than in females of any age. It ends close to the vertical from the anterior edge of the cartilaginous eye-stalk. Not even a stump is found in the region of the female barbel. Of the serial photophores the most developed are those of the ventral series, but even in these the pigmented frames are only partially developed and the A–C series is completely lacking. The lateral serial lights are much smaller and less distinct, dying out completely fully twenty myomeres in front of the anal fin. The anterior one or two branchiostegal organs are undeveloped also. Probably none of the serial lights is as yet functional, although in slightly older male post-larvae they all showed a distinct violet hue when fresh. The caudal lights are rudimentary, but a moderate amount of luminous granular material is already present on the unpaired fins.

Post-larval Male Osteology: (Fig. 61b). As in the females of this stage, there is no trace of ossification in cleared and stained post-larvae, while in general conformation the cartilaginous elements of the skeleton are less than half-way between those of larvae and adult males.

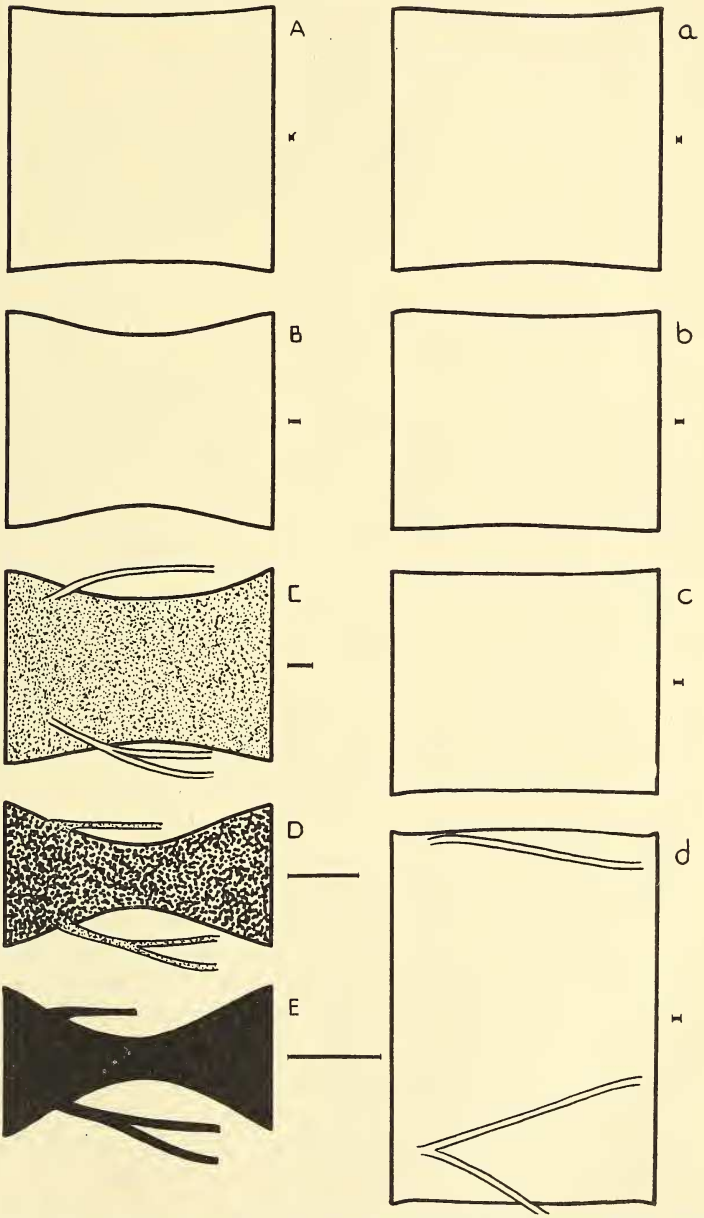


Fig. 61. Development of centra in females (left column) and males (right column). A and a, larvae, standard lengths 25 mm; B, female post-larva, 48 mm; C, female transitional adolescent, 90 mm; D, female adult, 267 mm; E, female adult, 350 mm; b, male post-larva, 45 mm; c, male adolescent, 35 mm; d, male adult, 32 mm. E is from *I. panamensis*, remainder from *I. fasciola*. Relative amount of ossification is indicated by shading, relative length of the vertebrae by the adjacent transverse lines.

Post-larval Male Digestive System: (Figs. 63C, 65C). The intestine still bulges ventrally, although it is well covered by abdominal epidermis, but the gut tip is relatively much shorter than in the larva, not reaching the end of the anal fin. The entire gut is correspondingly shorter—only 78 percent as long as the fish, opposed to almost 90 percent in young larvae. In contrast to the post-larval female there is little change from the larval organization of the various parts of the digestive system: the oesophagus still has one conspicuous bulge, the bile duct remains elongate, there is no trace of either caeca or spleen and the liver is still narrow and of a similar length to that of the late larva. In the breadths and proportions of the various sections of the gut itself, however, post-larvae of both sexes are very similar. The system is still functioning throughout, as shown by the remains of food in both oesophagus and intestine.

Post-larval Male Reproductive System: The testicles are clearly visible under low power magnification, though of small calibre compared with the intestine (the opposite is true in adult males). They measure .1 to .2 mm in diameter, and except anteriorly are located lateral rather than dorsal to the intestine. They originate well behind the stomach, at the fourteenth myomere, the left gonad slightly in advance of the right, as in mature specimens of both sexes. The sectional character of the testicles of adult males is not apparent, nor is the lace-like network of pigment found in the outer testicular membrane of more advanced specimens.

The intromittent organ is rudimentary, consisting of a small papilla behind the anus.

Transitional Post-larval Female and Adolescent Male: In appearance the transitional post-larval female corresponds to the adolescent male, as explained on p. 158. These periods are evidently short, though definite, in the development of both sexes, when the adult shapes are being rapidly assumed and the shrinking process is in full swing. Typical female and male examples are described below.

Transitional Post-larval Female Trawling Data: All of the characters except those of the skeleton are based upon the following specimen: Department of Tropical Research No. 16,842; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 792; July 8, 1930; 10 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 48 mm.

Transitional Post-larval Female Measurements and Counts: Total

length 51 mm; standard length 48 mm; depth 2.1 (in length 22.9); head 4.2 (in length 11.4); eye, horizontal, 1 (in head 4.2, in length 48); snout 1.1 (in head 3.8, in length 43.6), maxillary 3 (in head 1.4); snout to pelvic 18.5 (in length 2.6); dorsal origin to caudal base 27 (in length 1.8); anal origin to caudal base 17.1 (in length 2.8); pelvic rays 6; pelvic length 1.2; dorsal rays 64; anal rays 42; postorbital .25 (in head 16.8, in length 192); serial photophores: branchiostegals 13 to 14; lateral series, O–V 23, V–A 32; ventral series, I–V 34, V–A 32, A–C 17.

Transitional Post-larval Female External Characters: (Figs. 49D, 54B). The outer epidermis is fairly thick, with about half of the adult amount of pigment—that is, the fish is dusky brown with only the snout and jaws pale. There are 68 lateral, subdermal pigment spots. The subisthmal spots have almost vanished, and intestinal pigment persists only as a black ring encircling the anus.

This young fish is of about adult proportions as far as trunk and caudal peduncle are concerned, relatively deeper than the post-larva, with the maximum depth at the shoulder instead of near the middle of the length as in earlier stages. The tail also is slimmer, though not as reduced as in the mature female.

The head, however, is still large, as are the eyes. The latter are firmly fixed in their sockets, with the lenses covered by membranes connecting with the orbits, and they are round, not vertically elongate as in earlier stages; the posterior half of each iris is broader than the anterior. The stalks, traceable externally by pre-orbital bumps, are completely and tightly coiled down in cavities beneath very thin coverings of skin. The original attachments to skull and eye-balls persist. The snout is proportionately shorter than in the post-larva, though longer than in the adult. The premaxillary ends at the vertical from the anterior part of the eye, the maxillary an eye's diameter behind the orbit, and the mandibular angle slightly behind this—in all three bones a great advance is represented over the post-larval stage.

The teeth are about half developed, both in number and in relative length. In both premaxillaries and maxillaries are several teeth, and 9 or 10 are developed in each half of the mandible. In each jaw the longest teeth are in the positions of the longest fangs of the adult. In the lower jaw the arrangement is not entirely symmetrical.

The opercles are incomplete, the posterior gill arches being uncovered.

Of the large larval pectoral only a low, rayletless nodule remains, almost as well pigmented as the skin. The pelvics are short, the rays distinct and rather thickly webbed.

The dorsal is intermediate in the length of its base between the post-larval stage, where it commences only a little in front of the anal, and the adolescent, where it has reached its final, adult position above the pelvics; in the present specimen it is far in advance of the anal, but well behind the pelvics. The rays are, of course, all formed, as in the post-larva. The anal is of nearly adult extent. The caudal is contained 16 times in the standard length, making it twice longer relatively than in the adult female, but shorter than in the post-larva.

Of finfolds only traces remain except above the pelvics in front of the dorsal fin. Here there is a large, fleshy frill which is the result of the extension of the dorsal rays forward along the back: In its course the expanding fin has shoved ahead of it the dorsal finfold (always the deepest portion) before it could be absorbed; consequently it has accumulated in the frill-like tissue just described, disappearing even more slowly due to the local concentration of its mass. This accounts for its persistance far into the adolescent stage, to a period when other fishes have long since lost all trace of this juvenile character. In the present specimen, this portion of the fold measures 1.5 mm in length, is half as high and has a posterior dark spot.

The antorbital apparently has only the dorsal centre functional, as the lower part of the organ is covered with skin. The postorbital is placed under the posterior margin of the eye, far in advance of the mandibular angle, instead of above it as in the post-larva. The barbel has been broken off short in this specimen, but in other comparable ones it is longer and slimmer than in the post-larva but still imperfectly formed and lacking in pigment. The serial organs, as in the post-larva, are fully formed and in this specimen retain tinges of violet even after three years in alcohol. Both caudal lights are partially developed and there is a moderate amount of luminous granular material on the unpaired fins, but no trace as yet of luminescence in the teeth, of photophores along the first pelvic ray, or of lesser head and body photophores.

Transitional Post-larval Female Osteology: There is no ossifica-

tion. The cartilaginous elements in shapes and relations show little advance over those of the post-larva.

Transitional Post-larval Female Digestive System: (Fig. 62D). The intestine is fully enclosed within the body cavity save for a vestigial external tip. Due to the increased length of the caudal peduncle the gut now measures only 62 per cent of the standard length, or little more than in the adult. Except for a small amount of pigment and an enlarged stomach the digestive organs are of the same size and in the same positions as in the post-larva. The stomach, still very short, measures 3.5 mm (13.7 in length of fish). The oesophagus and proximal portion of the stomach have a thin sprinkling of pigment, but on stomach's distal half and over the coelomic lining is only the faintest dusting of minute chromatopores.

Transitional Post-larval Female Reproductory System: The gonads are rudimentary. There is a distinct gonopore on a papilla behind the anus.

Adolescent Male Trawling Data: All of the characters except those of the skeleton are based upon the following specimen: Department of Tropical Research No. 14,988; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 576; May 14, 1930; 10 miles south of Nonsuch Island, Bermuda; 700 fathoms; Standard length 35 mm.

Adolescent Male Measurements and Counts: Total length 38.5 mm; standard length 35 mm; depth 1.5 (in length 23.3); head 3.9 (in length 9); eye 1 (in head 3.9, in length 35); snout 1.2 (in head 3.3, in length 29.2); maxillary 2.6 (in head 1.5); dorsal origin to caudal base 15 (in length 2.3); anal origin to caudal base 9 (in length 3.9); dorsal rays 55; anal rays 40; postorbital .7 (in head 5.6, in length 50); serial photophores: branchiostegal organs 12 to 13; lateral series, O–A 50; ventral series, I–A 60, A–C 20; penis length .5 (in eye 2).

Adolescent Male External Characters: (Figs. 50D, 55B, B′). This adolescent male most nearly approaches the transitional post-larval female in appearance: the pigment is of about the same amount (the fish is half as dark as the adult female, but not much lighter than the adult male), with 66 lateral, subdermal spots; the maximum depth is typical of the adults of the species (but the deepest point on the body is toward the middle of the length—as is true even in adult males—and not at the shoulder as in all females past the post-larval stage); also as in the transitional post-larval

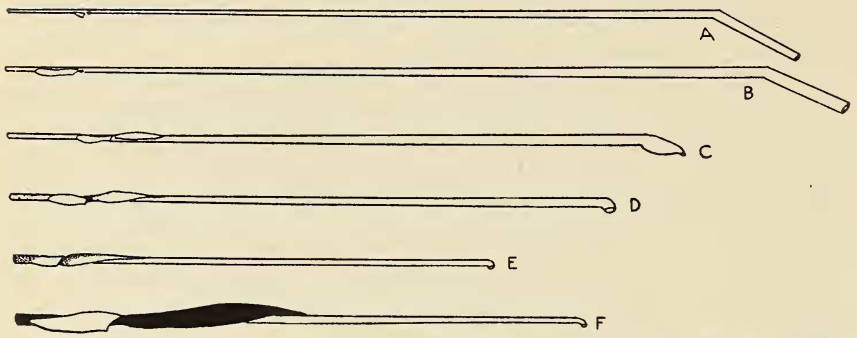


Fig. 62. Diagrams showing development of alimentary canal in female. Lateral views, left side. A, larva, standard length 16 mm; B, larva, 25 mm; C, post-larva, 45 mm; D, transitional post-larva, 48 mm; E, adolescent, 45 mm; F, adult, 267 mm. The guts are drawn to show the relation of their total lengths to the standard lengths, thus that of the 25 mm larva is 88% as long as the fish while that of the 45 mm adolescent is only 50% as long as that specimen, or relatively little over half as long as in the larva. In each case the liver is the anterior of the two organs represented, the stomach the posterior.

female the head, eye and snout are large compared with these organs in the adult female, but again they are of the final proportions for mature males. The position of the eyes too is comparable with that in the corresponding female stage, as these organs are completely sessile, perfectly round with the lens forward in each iris, and the stalks shriveled close in front of them and barely covered by thin areas of skin. The jaw bones are more larvoid than in the corresponding female, and completely edentulous.

The opercles, also as in the parallel female, are incompletely formed, the pectoral consists of a nodule only, and the dorsal and anal, though composed of typically adult numbers of rays, have not quite attained the adult male extent. The caudal is of adult male length, contained 10 times in the standard length, but it is over 3 times as long relatively as in the adult female.

A moderate sized finfold persists dorsally, with a concentrated frill of tissue immediately in front of the dorsal fin exactly as in the transitional post-larval female.

The antorbital, in its permanent position beneath the anterior corner of the eye, has now but one functional center, the upper, as in the female. The postorbital, still well separated from the antorbital, is already greatly swollen, but little over half its adult size. It commences under the posterior portion of the eye and ends well behind it, having a maximum length of about three-fourths the

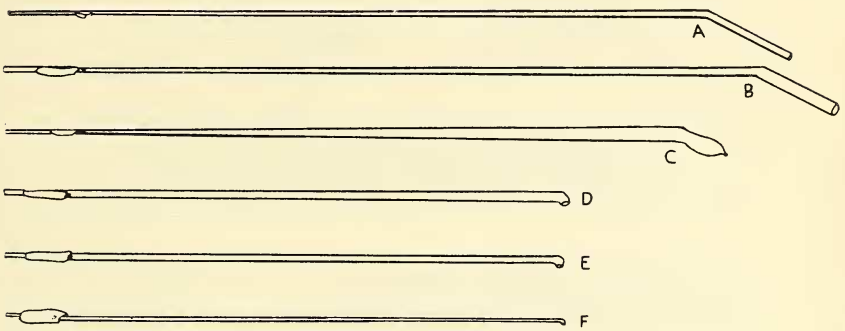


Fig. 63. Diagrams showing development of alimentary canal in male. Lateral views, left side. A, larva, standard length 16 mm; B, larva, 25 mm; C, post-larva, 40 mm; D, adolescent, 35 mm; E, transitional adolescent, 35 mm; F, adult, 38 mm. The sexually indeterminable larvae of Fig. 62 have been repeated. In each of the cuts the stomach is the minute papilla behind or beneath the larger liver.

diameter of the eye. There is no trace of a barbel. The serial photophores have the lateral series shorter by several organs than in the female, but the same is true of adult males. The ventral caudal light alone is distinguishable, but there is more granular luminous material on the unpaired fins than in the female. No jaw luminescence is developed.

Adolescent Male Osteology: (Figs. 60, 61c). There is no trace of ossification. The masculine characteristics of the bones, as described later in connection with the adult male, are beginning to be apparent.

Adolescent Male Digestive System: (Figs. 63D, 65D). The alimentary canal is entirely enclosed within the body cavity, but is traceable throughout its length by a pale colored bulge along the ventral profile. Vestiges of the larval external end of the intestine persist in the prominent anal papilla. As in the transitional post-larval female the total length of the gut is now reduced to three-fifths of the standard length, or equal to its extent in the adult male. Most important in the digestive organization is the incipient degeneration of the system: The end of the oesophagus is completely cut off from stomach and intestine by a transverse constriction, so that ingestion of food is now obviously impossible. The stomach is no longer than in the post-larva and the bile duct is reduced, bringing the gall bladder closer to the pyloric region. The liver, on the other hand, is a third again as large as in the post-larva and two rudimentary caeca are distinguishable. In average calibre the gut is about

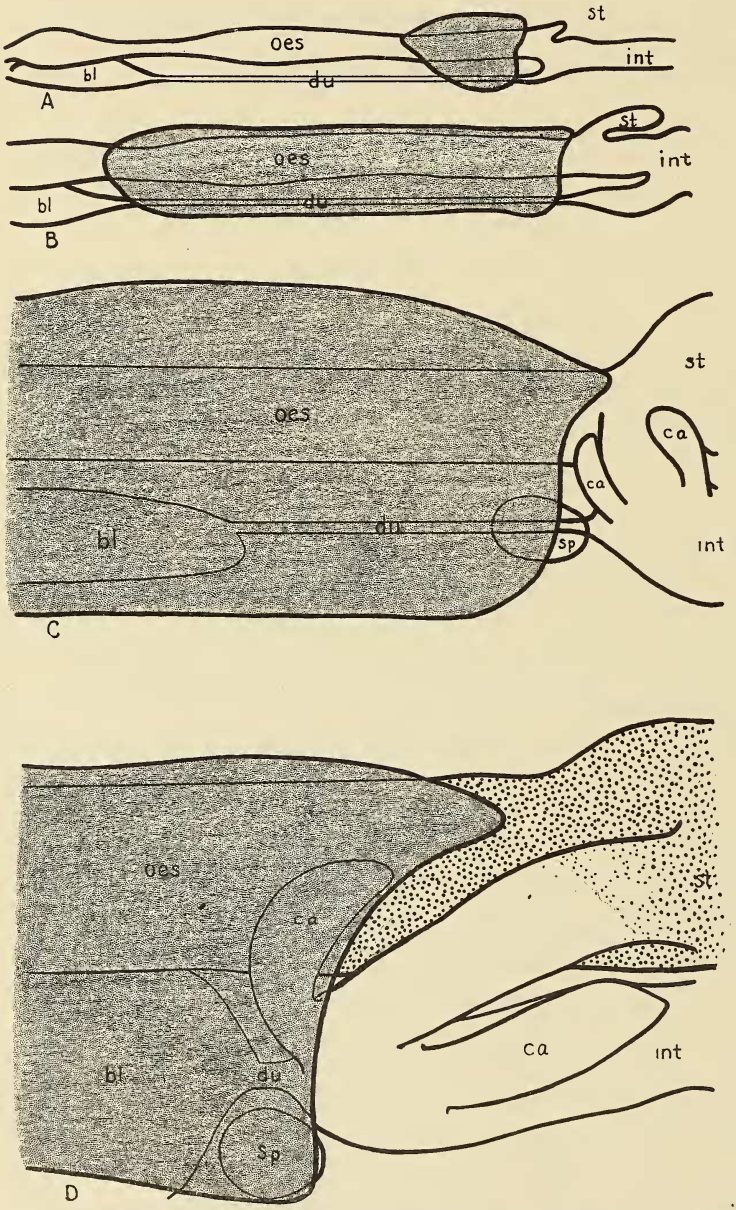


Fig. 64. Development of pyloric region in female. Ventral views. A, larva, standard length 16 mm; B, larva, 25 mm; C, post-larva, 45 mm; D, adolescent, 45 mm. The liver is indicated by the shaded portion. Abbr.: bl, gall bladder; ca, caecum; du, bile duct; int, intestine; oes, oesophagus; sp, spleen; st, stomach. (× 57).

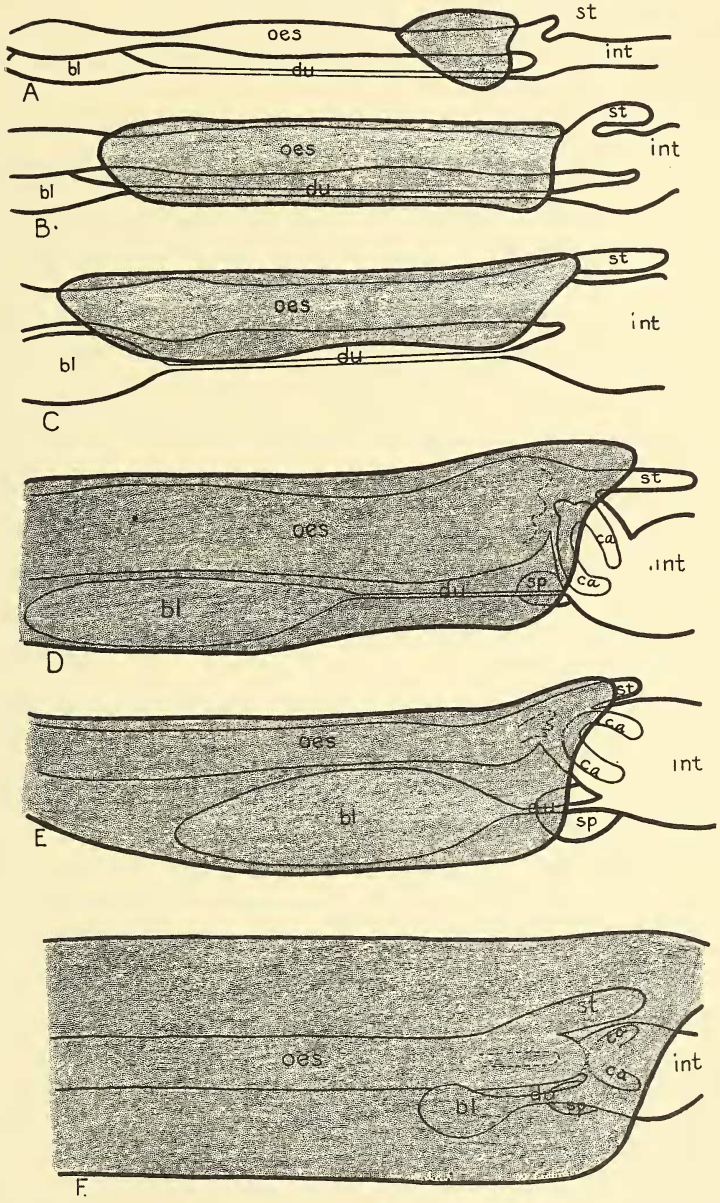


Fig. 65. Development of pyloric region in male, ventral views. A, larva, standard length 16 mm; B, larva, 25 mm; C, post-larva, 40 mm; D, adolescent, 35 mm; E, transitional adolescent, 35 mm; F, adult, 35 mm. The liver is indicated by the shaded portion. Abbreviations as in Fig. 64. (× 57).

equal to that of the post-larva, but the terminal portion is only slightly expanded. There is a small rounded spleen above the pyloric end of the bile duct.

Adolescent Male Reproductory System: The gonads are .25 mm in diameter, about equal to that of the intestine. Pigment is appearing in a series of broken transverse bands. There is still no trace of the testicular constrictions found in more advanced specimens. The intromittent organ behind the anus is unpigmented, half as long as in the adult and shorter than the first anal rays.

Adolescent Female and Transitional Adolescent Male: As explained on p. 158 the adolescent female in appearance corresponds most closely to the transitional adolescent male. It is during these periods in the lives of each that the last vestiges of larval eyestalks, pectoral fins and finfolds gradually disappear. Individual examples of both sexes are described below.

Adolescent Female Trawling Data: All of the characters except those of the skeleton are based upon the following specimen: Department of Tropical Research No. 23,148; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1270; September 7, 1931; 10 miles southeast of Nonsuch Island, Bermuda; Standard length 45 mm.

Adolescent Female Measurements and Counts: Total length 48.5 mm; standard length 45 mm; depth 1.9 (in length 23.7); head 3.4 (in length 13.2); eye .8 (in head 4.3, in length 56.3); snout 1 (in head 3.4, in length 45); maxillary 2.6 (in head 1.3); snout to pelvic 17 (in length 2.6); dorsal origin to caudal base 28.3 (in length 1.6); anal origin to caudal base 16.7 (in length 2.7); pelvic rays 6; pelvic length 1.5; dorsal rays 60; anal rays 38; postorbital .22 (in head 15.5, in length 204.5); barbel 3.6 (in head .9); serial photophores: branchiostegal organs 13 to 14; lateral series, O–V 23, V–A 33; ventral series, I–V ca. 34, V–A 34, A–C 17.

Adolescent Female External Characters: (Figs. 49E, 54C, C′). The 68 larval subdermal spots are fading but distinct, although due to the dark general pigmentation they are faint when viewed with the skin intact. The external pigment is not however completely developed, and the jaws are still pale.

In relative depth and in size and appearance of the head this adolescent specimen agrees with adult females, but the eye and snout are both relatively still large. Inside the snout there is visible

the last trace of juvenile cartilaginous eye-stalk: all except a part of a single spiral has been absorbed.

In the jaws the teeth are developed only slightly more highly than in the transitional post-larva, being short and scattered; in the premaxillaries there are 5 or 6 pairs, 1 or 2 pairs in the maxillaries and about 8 teeth in each mandibular ramus. Both vomer and palatine are edentulous but the basi-branchials have 2 pairs of teeth, strong, long, curved and posteriorly directed—the most efficient teeth in the mouth during this period.

The opercles are practically complete.

Of the early pectoral fins only a scar remains. The pelvic is relatively not as long as in the adult, but the dorsal and anal are fully developed, the first four dorsal rays being in advance of the pelvics. The caudal, however, is still relatively two and one-half times as long as in the adult female, or about one-thirteenth of the standard length.

A small, fleshy tab, reduced compared with the same finfold remainder in the transitional post-larva, is the only trace of finfold in this specimen.

The antorbital still has a single, upper, fully functional center. The postorbital is below and behind the posterior margin of the orbit and is somewhat over three times longer relatively than in the adult, actually a little more than half as large. The barbel is slightly longer than the head, instead of more than twice as long, as in large specimens, and has the stem merely dusted with pigment. The bulb is completely colorless, with none of the details formed of the delicate flanges and filament of the adult: the translucent tissues of the older fish are fleshy and opaque in the adolescent, while the future filament is a thickly tapering projection. Serial photophores, as in previous stages, are all present and functional, and the ventral caudal light and luminous fin granules are highly developed. The upper caudal light remains rudimentary and there is no trace either of tooth luminescence or of pelvic photophores.

Adolescent Female Osteology: There is no trace of bony tissue. The elements in general, however, show advanced development, save for the still juvenile juxtaposition of the bones entering into the angle of the jaw and the conformation of the vertebrae, which still are but slightly excavated.

Adolescent Female Digestive System: (Figs. 62E, 64D). Exter-

nally there is no trace of the gut. Its total length is only 50 per cent of the standard length of the fish, and it is now relatively shorter than at any other stage of development. Compared with the post-larva, the stomach is longer, extending to a point three-fifths of the distance between opercle and pelvic, its length contained 10 times in the length of the fish; the oesophagus and dorsal anterior portions of the stomach are more densely pigmented; the liver is broader, but relatively shorter, with the left tip pronouncedly longer than the right; the caeca and the pyloric arm joining stomach and intestine are of adult form and proportionate size; the bile duct has been further reduced, drawing the bladder close to the pyloric region, and the spleen is now slightly to the right of the bile duct. There is no noticeable change in the calibre of the gut, save that it is scarcely expanded distally.

Adolescent Female Reproductive System: The gonads are as yet rudimentary.

Transitional Adolescent Male Trawling Data: All of the characters except those of the skeleton are based upon the following specimen: Department of Tropical Research No. 18,009; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 854; September 6, 1930; 10 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 35 mm.

Transitional Adolescent Male Measurements and Counts: Total length 38.2 mm; standard length 35 mm; depth 1.8 (in length 19.4); head 3.7 (in length 9.5); eye .97 (in head 3.8, in length 36.1); snout 1 (in head 3.7, in length 35); maxillary 2.3 (in head 1.6); dorsal origin to caudal base 19 (in length 1.8); anal origin to caudal base 9 (in length 3.9); dorsal rays 51; anal rays ca. 33; postorbital 1 (in head 3.7, in length 35); serial photophores: branchiostegal organs 12; lateral series, O–A 43; ventral series, I–A (end of lateral series) 50, A–C 25; penis length .6 (in eye 1.6).

Transitional Adolescent Male External Characters: (Figs. 50E, 55C, C′, C²). The immature male does not differ significantly from the mature specimen subsequently to be described except in the following particulars: The skin is not as deeply pigmented as in the adult; the snout is not as highly arched; traces of eye-stalk remain beneath the skin of the snout; the mandibular angle falls at a point only about half the width of the eye behind the orbit, instead of about twice the eye's diameter as in the adult; there is a trace of dorsal fin-

fold especially concentrated in a frill-like tab in front of the dorsal; the postorbital is about three-fourths as large as in the mature male, connected with the antorbital only by a dark bridge of pigment, the luminous center commencing far back under the posterior part of the eye; the lateral series of photophores ends well in front of the anal origin, instead of above the first few anal rays; and, finally, the dorsal organ of the caudal is rudimentary.

When compared with the corresponding adolescent female, the general differences between the two, as opposed to the strictly sexual, are much more apparent than in earlier stages. Especially striking are the medially thickened body, large eyes, and short jaws of the male.

Transitional Adolescent Male Osteology: In general conformation the elements of the skeleton are very similar to those of the adult male, subsequently to be described. There is still, however, no trace of ossification.

Transitional Adolescent Male Digestive System: (Figs. 63E, 65E). As in both adolescent and adult male the gut measures three-fifths of the standard length. Compared with the adolescent, the diameter of the oesophagus is reduced by the infolding of its walls at the expense of the bore; the partition between oesophagus and pyloric region is thickened; the liver is slightly longer, its posterior tip partially overlapping the still rudimentary stomach and caeca; and the bile duct is further reduced in length. Of all these changes the last alone takes place also in the corresponding, adolescent female. The immaturity of the male is shown in comparative narrowness of the liver, unshrunken gall bladder and relatively wide intestine.

Transitional Adolescent Male Reproductory System: The testicles are no larger than in the adolescent, being of the same diameter as the intestine, but the pigment now forms a fairly continuous network over their surface, instead of the former series of broken bands and the constrictions so typical of the testicles of the adult are indicated in this transitional adolescent. The intromittent organ is still short and white, but is already stiffened by attachment to the first anal ray.

Transitional Adolescent Females: (Fig. 47). The Bermuda collection contains 15 specimens which are referred to this growth stage, ranging between 48 and 161 mm. From true adolescents they differ in their dark pigmentation, being usually as dark as the adults;

in the superior dentition; in the lack of traces of eye-stalks, pectoral scars and finfolds; in the fully shaped barbel; in the practically adult size and pigmentation of the stomach; and, among larger specimens, in the advanced ossification and partial development of the gonads.

From the adult specimens the transitional adolescents differ in having the premaxillary teeth alone completely developed, those of the maxillary and posterior part of the mandible being few and very small; in having the barbel bulb entirely or partially unpigmented; in the slight ossification of the skeleton; and in the immaturity of the gonads.

It is during this stage that a bony skeleton is built up. The first areas to show ossification are the jaws, parasphenoid, hyomandibular, preopercle, frontal ridges, main opercular ridges, pectoral girdle, hyoid arch and branchial apparatus. Ossification of the vertebral column (Fig. 61C) follows, proceeding posteriorly. The posterior parts of the column and the finrays show no stain until the fish is well over 100 mm in length, while the brain case and minor elements of the head may be almost unossified even in fully mature specimens. Strengthening of the bones seems to continue throughout life.

Adult Females and Males: The adult characters of both sexes are tabulated on pp. 156–157.

The 4 adult females measure 190, 242, 267 and 270 mm respectively. The smallest of these has the transitional adolescent characters of incomplete maxillary and posterior mandibular teeth, but allowing for its small size the eggs and ovaries are relatively about as well developed as in the larger non-breeding specimens of 242 and 270 mm. The 267 mm specimen alone is in full breeding condition and is described in detail below.

A mature male with ripe spermatozoa is treated subsequent to the female.

Adult Female Trawling Data: All of the characters are based upon the following specimen: Department of Tropical Research No. 21,937; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1137; August 6, 1931; 9 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 267 mm.

Adult Female Measurements and Counts: Total length 275 mm; standard length 267 mm; depth 11 (in length 24.3); least depth 3 (in length 89); head 18 (in length 14.8); eye 2.6 (in head 6.9, in

length 102.7); snout 3.5 (in head 5.1, in length 76.3); snout to pelvic 94 (in length 2.8); pelvic to anal origin 74; dorsal origin to caudal base 181 (in length 1.5); anal origin to caudal base 97 (in length 2.8); pelvic rays, left side 6, right side 8; pelvic length 16; pelvic origin under fourth dorsal ray; dorsal rays 68; anal rays 44; caudal rays XIV + 10 + 10 + VII; postorbital .4 (in head 45, in length 667.5); barbel 43 (2.4 times head); serial photophores: lateral series, O–V 24, V–A 34; ventral series, I–V 35, V–A 34 (16 to anal origin), A–C 14.

Adult Female External Characters: (Fig. 49F, 66). In the fresh specimen the skin was dark brownish black, as was the barbel stem. The core of the barbel bulb also was dark, with the translucent white, enveloping membranes speckled proximally with black; the anterior filament was pale lemon yellow. All of the serial photophores were blue violet, those of the ventral series being set in gilt frames. Both upper and lower caudal lights were bright golden yellow. Even in the comparatively pale, preserved specimen there are subdermally faint traces of the lateral larval chromatophores as well as a partial general wash of dark pigment.

The characteristic extreme slenderness of the genus is very evident in this large example, as is the gradual and symmetrical tapering from the shoulders to the much attenuated caudal base. The crown of the head is scarcely raised above the shoulders, the moderately short snout sloping from here rather abruptly to its blunt tip. The lower jaw curves slightly upwards, projecting a little beyond the tip of the premaxillary. The eye, well developed but relatively smaller than in preceding stages, does not interrupt the dorsal profile, and neither internally nor externally is there the least trace of the larval stalk of cartilage. The nostrils are placed high on the snout, slightly nearer to its tip than to the eyes.

All except the smallest of the teeth are depressible and bicuspid, as is typical of the genus, very unequal in length, and show a tendency to be arranged in groups, the members of each increasing in size posteriorly. In the left half of the mouth the numbers of teeth are as follows: The premaxillary holds 11, the seventh, third and eleventh respectively the longest; the maxillary has two anterior series of erect teeth of 6 and 4 teeth each, the former in a graduated row, the latter much smaller and of nearly equal size; following these are several minute, erect denticles. The mandible holds 29 teeth, the fifteenth, sixth and thirteenth longest, larger than any of

Fig. 66. Heads of adult female, standard length 267 mm, and adult male, standard length 38 mm, showing relative size. ($\times$ 4.5).

the upper teeth; the last 10 are small, in two series of 6 and 4 which correspond to the anterior maxillary teeth, although they are not as large. In addition there are several small replacement teeth. On the right side of the mouth the number and relative size of the teeth are very similar; the chief differences are the presence of an extra, minute, anterior, premaxillary tooth and the shortness of the fifteenth mandibular fang, which is obviously replacing a lost tooth. There is a single pair of teeth on the vomer, 2 teeth on each palatine and 4 pairs on the basibranchials. Finally, on each of the third pharyngobranchials are two groups of 4 to 6 and 3 to 5 teeth each.

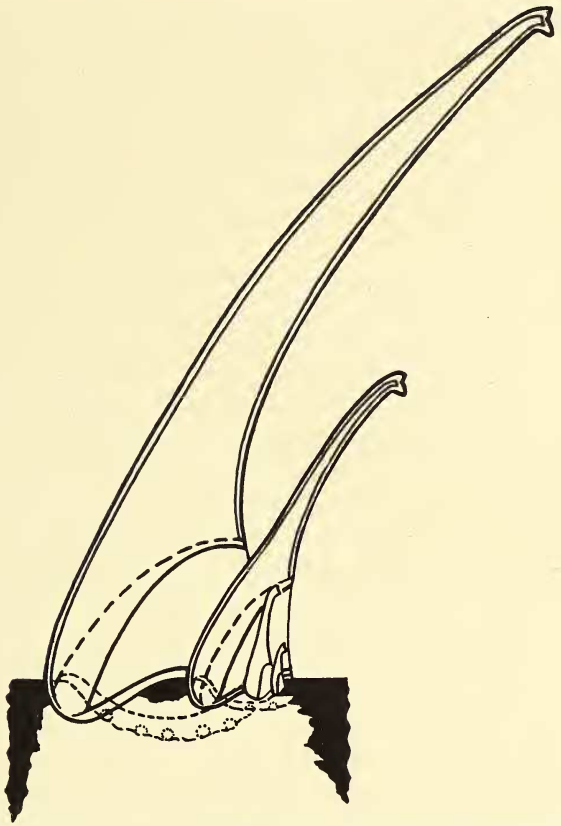


Fig. 67. Two fangs and two small replacement teeth from mandible of adult female, showing luminous basal cores and row of pores along inner edge of base. (× 20).

Within the translucent base of each tooth a considerable amount of bluish, luminous substance is visible (Fig. 67). After clearing and staining it is seen that this is held in a large, triangular cavity occupying more than the posterior half of the base of the tooth and thrusting far into it, its apex reaching one-fourth (in large fangs) to one-half the distance to the barbed tip. It recalls luminous buccal mucous which covers the teeth in some deep-sea fish. This internal dental substance must combine the qualities of supplying the material for tooth replacement and growth with luminosity. The sides of the tooth overlap the inner and outer margins of the jaw, so that a strongly arched floor is formed. Completely encir-

cling the very base of the vertical walls is a narrow rim of especially firm bony tissue; on the inner side this is punctured with about half a dozen pores, giving access to the cavity. All of the cavity boundaries except this basal rim and the anterior and upper walls (which are of the bony substance of the tooth proper) are of a delicate, easily ruptured, perfectly transparent, cartilaginous material. The tooth itself is faintly striated with alternating series of short, vertical lines.

All trace of a pectoral nubbin has disappeared. The pelvics originate under the fourth dorsal ray, and though the rays are rather strongly developed they are unwebbed and quite short. Along the first ray is a row of graduated, round, white spots, largest proximally. Except for the luminescence possibly shed by these organs, the pelvic fins cannot be of much practical value. Due to their comparative feebleness their use as claspers of the male during copulation seems out of the question. On the right side of this individual fish, 2 extra pelvic rays are developed behind the normal group of 6; these abnormal rays are shorter than the rest (which are of approximately equal lengths), separated from them and from each other by distinct spaces and are quite feeble. All except the last dozen or so of the dorsal and anal rays are separated by broad and nearly equal spaces; the most posterior rays, however, become successively more closely crowded. The webbing of these unpaired fins is perfectly transparent and appears exceedingly delicate, but is actually reasonably strong. Anteriorly it does not reach the tips of the rays. The caudal fin is contained 33.4 times in the standard length, with the fork moderately deep and the lower lobe considerably the longer. The long, true terminal caudal rays have single rows of dark dots, possibly rudimentary photophores, in the webbing between each two rays; these organs are completely lacking between the nine central, short rays which form the base of the fork. The luminous material close to the fin's base, subsequently to be described, prevents any spreading of the rays, and there seems very little mobility to the fin as a whole, as the elements are all very flat and soft. All of the terminal ones have the numerous cross bars of typical rays—joints which are as usual lacking in the dorsal and ventral raylets.

A trace of the antorbital photophore survives in a small crescent of luminous tissue below the lower front corner of the eye. The

postorbital is a minute round photophore facing outwards, set in a somewhat larger, black frame.

The barbel stem is fully pigmented clear to the terminal swelling; the core of the latter is dark brown, save for the attenuated tip, while the translucent, proximal envelope and expanded, basal portion of the posterior filament are speckled with brown. The anterior and posterior membranous flanges running the length of the distal half of the bulb are perfectly clear. In the fresh specimen the terminal half of the proximal, anterior filament, with the characteristic swelling of the species, was pale lemon yellow. At the base of the bulb posteriorly is a small, rounded luminous body. The general structure of the barbel, however, makes it probable that its function is tactile or receptive rather than light-giving.

The serial photophores, as well as those of the branchiostegals and the two opercular lights, were blue violet in the fresh specimen. Each of the lateral and ventral lights is set near the middle of a myomere. In the preserved fish the gilt frames of the ventral organs, so conspicuous in the new-caught state, are invisible, traces remaining only in somewhat paler skin immediately surrounding each light. All of the organs are directed obliquely downward.

Lesser lights of the head and body are few in number compared with their abundance in many of the Melanostomiatidae, but are concentrated in the same regions. They are moderately numerous on both upper and lower jaws, sparse on cheeks and opercles and absent on the top of the head. The barbel stem has a few irregularly placed, minute organs, especially distally. On the body (Fig. 68) the myomeres are outlined with single rows of closely set, microscopic organs averaging 50 to each row from dorsal to ventral profile. The myomeres themselves have a few larger lights. These tend to form a median vertical line of from 6 to 10 organs in the middle of each myomere, each line beginning slightly above the mid-line and ending above an organ of the lateral series. In some cases this vertical row continues up to the dorsal profile as a more irregular line of much smaller organs. Near each central line there are usually half a dozen or more odd organs scattered mid-laterally and without arrangement. Across each myomere between the lateral and ventral series are two rough, concentric arcs of small organs with each lateral light the center of the incompleted circles. The lower series of arcs is the more conspicuous of the two all along the body. Each arc is

composed of about a dozen organs, not equally or symmetrically spaced. In the ventral mid-line is a continuous double row of similar organs, also numbering in each row about 12 to a myomere. On the caudal peduncle the anal fin passes between the two rows, and the organs in this region are less numerous and more irregular.

There is a conspicuous line of whitish luminous tissue along the upper margin of the maxillary immediately below the postorbital light. On the body similar whitish patches alternate with the serial organs at least as far back as the pelvics, and, along the profiles, with the ray bases of the dorsal and anal fins. The row of bead-like

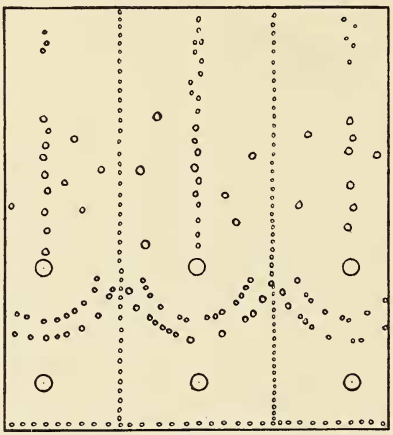


Fig. 68. Arrangement of photophores in adult female, between dorsal and ventral profiles, showing serial organs and lesser lights. From the mid-trunk region of a specimen 267 mm in standard length.

lights on the first pelvic ray has been already described. In this specimen the luminous granules which are so conspicuous on the dorsal and anal fins of the males are almost lacking.

Alternating with the bases of the twelve supra-caudal raylets are small patches of lemon yellow luminous material. Two large organs of the same substance lie at the bases of the last three rays extending downward over the flesh of the base of the caudal fin for a short distance. The whole arrangement is reminiscent of the luminous supra-caudal scales of the Myctophid genus *Lampanyctus*. The uppermost five, true, terminal, caudal rays have luminous granules between them, while the lowermost support the largest of the caudal organs; this extends for about 2.7 mm over the basal

portions of the middle lower rays, with a smaller distal finger lying ventral to the parallel from the main organ. These latter yellow organs were exceedingly brilliant in the fresh fish. The seven infracaudal raylets also have small amounts of luminous material alternating with their bases.

Adult Female Osteology: In the study of the osteology of the adult female, the 267 mm specimen of *Idiacanthus fasciola* just described has been compared, after clearing and staining, with an example of *I. panamensis* measuring 350 mm in length (see page 237 for trawling data) and similarly treated. With the exception of the shape of the vertebrae the configuration of the bones in the two species is practically identical. The smaller fish, however, although in full breeding condition, is everywhere noticeably less strongly stained, while the skull proper and the teeth—both of which show strong ossification in the larger specimen—are more faintly colored. In other respects the relative ossification of various areas is very similar in both species: The jaws, parasphenoid, frontal ridges, hyoid and branchial apparatus and the barbel bone are most deeply stained, but the palato-pterygoid arcade, preopercle, opercular ridges, pectoral girdle, vertebral column, finrays and vertebral appendages also show strong ossification. In neither specimen do the opercle, subopercle and interopercle show more than traces of stain.

The similarities in the shapes and relations of the bones in these two fish indicate that the variation in amount of ossification is due, not to specific differences, but to the continued deposition of bony matter after full maturity has been attained.

The various portions of the skeleton are described in detail below.

Adult female skull: At first glance the skull seems to be poorly ossified, even in the larger specimen, but this is due to the small size of the cranium proper and to the great length and slenderness of the principal components of the opercular and the oro-mandibular areas and of the branchial apparatus. Individually many of the bones show thorough but delicate ossification.

The cranium, viewed from above, (Fig. 69) shows an abruptly broadened posterior portion, narrowing to about one-half of the width in front of the sphenotics, thence sloping forward to expand again into the mesethmoids. In both *I. fasciola* and *I. panamensis* of the present collection the cranium is considerably broader posteri-

orly than is shown in the figure of Regan and Trewavas (1930, p. 48, fig. 20B). This distinction is true even in smaller specimens.

The elements of the broad, posterior brain case proper are strongly fused, in some cases the limits of the bones being evident rather by varying thickness of ossification than by actual lines of demarcation.

The largest element of the postorbital area is the supraoccipital. Posteriorly it curves backward over the exoccipitals, while on each posterior side the large, rounded epiotics describe a curve in its contour. Anteriorly, its exact extent is lost beneath the over-growing frontals, leaving exposed a good-sized anterior tongue and steeply sloping sides. The extreme center is marked by a mass of bubble-like mucous openings. The pterotics lie outside the epiotics, equal to the latter in area, but irregularly elongate antero-posteriorly, projecting strongly backward at the postero-lateral angles of the cranium. The sphenotics resemble in size and general shape the epiotics. They form the major parts of a pair of triangles anterior to the pterotics, the apex of each projecting sharply out on the side of the cranium.

The mid-portion of the skull, composed wholly of the frontals, is narrow only in comparison with the wide posterior area. The frontals are of great extent, the two anterior points widely divergent. Along the midline this pair of bones is closely apposed except for the central third of their length. Here they are considerably divergent. Behind this area they close up again, finally to separate, outlining the anteriorly directed tongue of the supraoccipital and sloping sharply posteriorly over the lateral extent of the supraoccipital to die out in an irregular line of ossification near the anterior edge of the epiotics. The most strongly ossified area of the entire cranium is that of the pronounced frontal ridges extending near the outer borders of the bones from the anterior tips as far back as the junctions with the sphenotics. From here posteriorly these ridges become covered tubes extending out to the very tip of the posterior projection of the pterotics.

Anterior to the frontals and hardly less strongly ossified are the two wide, lateral wings of the mesethmoid. In the center line anteriorly this bone curves abruptly downward and expands at once into a broad and almost transparent plate which covers the vomer. In no specimen are lateral ethmoids, figured by Regan and Trewavas

(*loc. cit.*) distinguishable from the surrounding tissue, even as cartilaginous elements. The nasal bones are much reduced, appearing only as two imperfect, short tubes near the center of each lateral mesethmoid wing.

Adult female palato-pterygoid arcade: (Fig. 70). The hyomandibular is a remarkably shaped bone with a trilobed head and a long slender body. The markedly ridged and strongly ossified center of the head sends a large, triangular flange upward, the flat, farthest edge of which articulates with the outer side of the pterotic. Downward and forward extends a second delicately ossified, wing-like flange while posteriorly a strong, narrow arm articulates with the main head of the opercle and the superior end of the preopercle. The remainder of the hyomandibular extends backward as a long and slender bone, slightly thickened in the mid-area and finally articulating closely with the ends of the preopercle and the quadrate. The quadrate in the shape of an elongate triangle has its superior profile closely applied along half of the elongate body of the hyomandibular. Just anterior to it, bounded above by the body of the hyomandibular and below by the pterygoid, lies the irregularly semicircular metopterygoid. Both of these bones are thin and leaf-like but decidedly ossified. The pterygoid is a long, thin, spine-like bone commencing at the lower anterior end of the quadrate; it extends forward parallel to, but at considerable distance from, the hyomandibular until it articulates with the palatine at about three-fourths of the distance from the angle of the jaw to the tip of the premaxilla. Just before its articulation it widens slightly. The palatine at its point of attachment is of equal width and then extends forward becoming narrow until it suddenly expands into a spoon-shaped enlargement at its attachment to the mesethmoid and the premaxilla. Halfway down its length it is armed with two or three pairs of strong, fang-like teeth. The vomer is small and supports a single pair of teeth slightly larger than those on the palatine. From this point backwards extends the strongly ossified, rod-like parasphenoid.

Adult female jaw apparatus: (Figs. 60, 70, 72). The bones of the jaws while slender and rod-like are strongly ossified and all of them support a powerful dentition. Each premaxillary has a pronounced upward projection at the point of juncture. From here it extends along the upper jaw for about forty per cent of its entire length.

The maxillary begins as a narrow, ossified splinter directly under the expanded portion of the palatine and extends backwards with gradually increasing surface, forming the actual edge of the jaw for the posterior sixty per cent. Throughout its length it maintains its narrow, rod-like character with very slight enlargement at its posterior attachment. For more than the posterior third of the entire length of the maxillary its upper profile is formed by the distinctly separate supramaxillary. The mandible is by far the largest and stoutest bone of the head. The dentary forms the major part, the articular showing as a broad wedge driven down the center to a distance of over half the entire length of the jaw. The angular is hardly to be detected as a separate element near the extreme inferior profile of the articulating process. For details of the dentition see page 197.

Adult female opercular bones: (Fig. 70). The opercular bones, while all present, are of the thinnest imaginable ossified tissue, being marked strongly only along their supporting ridges. From the large articular head of the opercle two strong, rod-like ridges diverge, one toward the upper edge and the other throughout its length to the posterior edge. Below this, only imperfectly demarcated, are the subopercular and the interopercular areas, continuing the delicate, membrane-like opercular contours. The preopercle on the other hand is a strongly ossified, rod-like bone extending from the posterior arm of the head of the hyomandibular and closely paralleling its body to the point of junction at the angle of the upper jaw. For about one-half of their length the two bones are firmly ossified together, separating just before the jaw angle to form a large, oval foramen.

Adult female circumorbital bones: (Fig. 69). The only structure which can be classed in this category is a supra-orbital appearing as a lateral expansion of the frontals. It is quite unossified, but of cartilaginous consistency.

Adult female hyoid arch: (Fig. 71). The upper end of the long, slender interhyal lies close to the hyomandibular, but is not definitely attached to any particular tissue, at about the beginning of its point of ossification with the opercular. The epihyal, which is only slightly longer than the interhyal, is about three times as wide and gives rise to five branchiostegals. One of these arises near the anterior end. The other four are bunched close to the articulation with

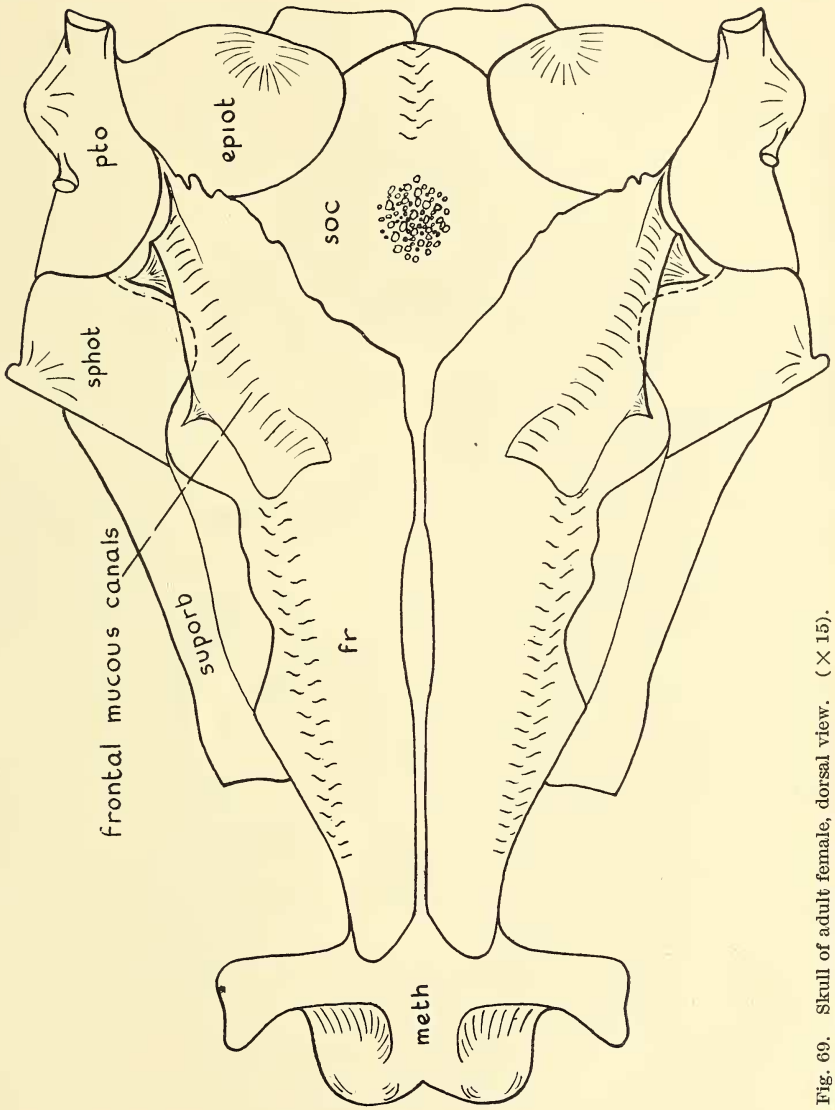


Fig. 69. Skull of adult female, dorsal view. (×15).

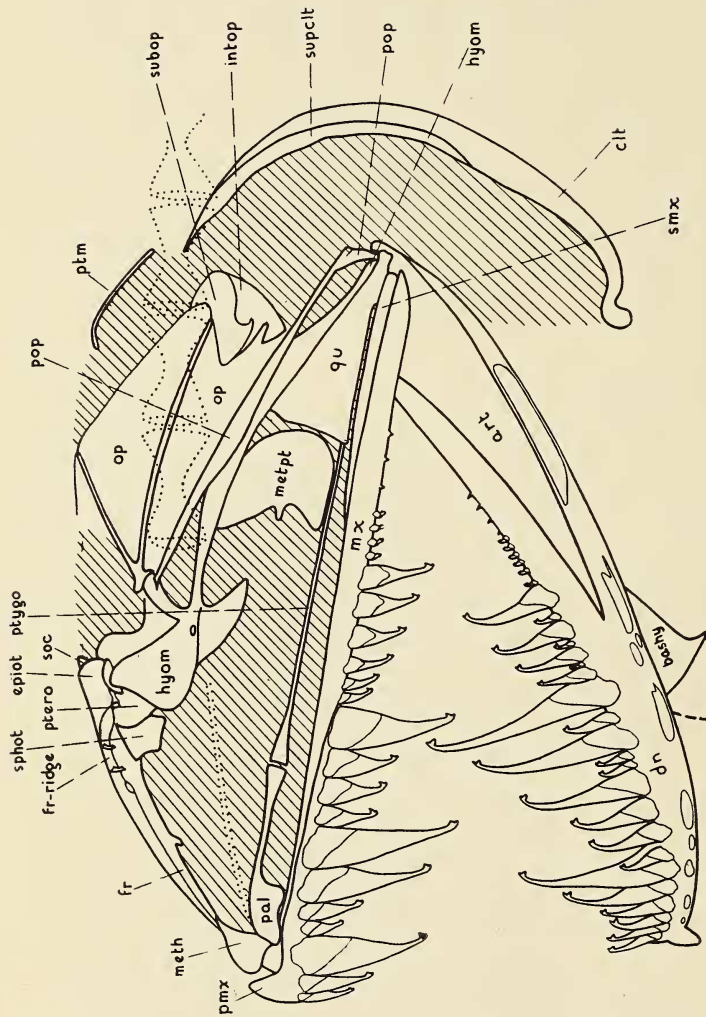


Fig. 70. Bones of head and pectoral girdle in adult female, lateral view. (× 5.5).

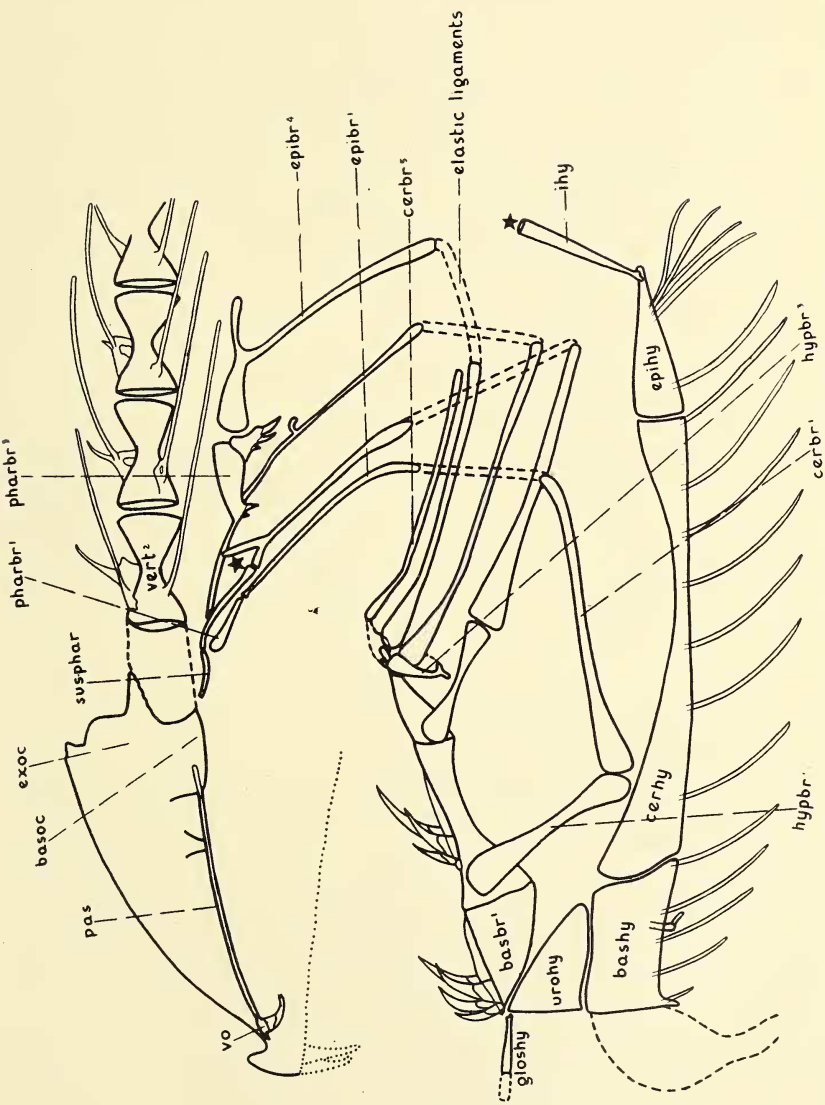


Fig. 71. Hyoid arch, branchial apparatus, and anterior part of vertebral column in adult female. The interhyal has been detached (normal position indicated by star) and the basibranchials pushed upwards in order to show all of the elements clearly. (× 5.5).

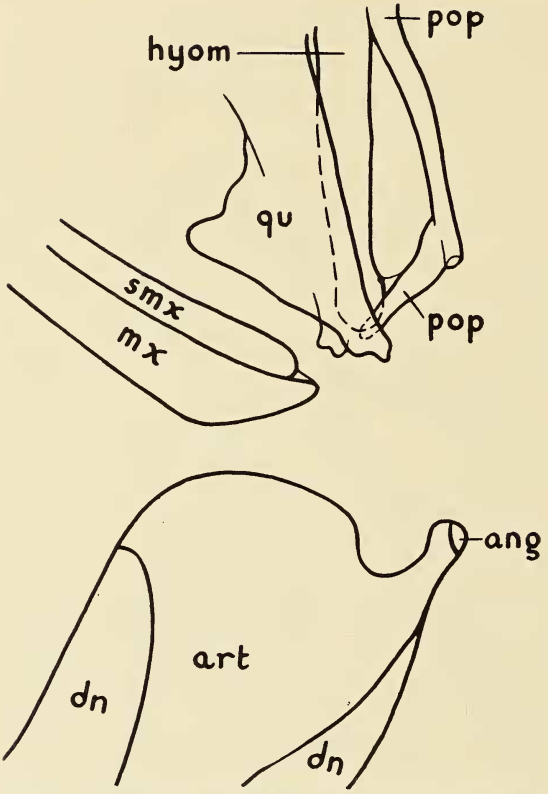


Fig. 72. Disjointed elements of jaw angle of adult female.

the interhyal and of these the posterior three seem to have but one definite point of insertion. The ceratohyal is three times as long as the epihyal, broad at both ends but gradually narrowing to an extremely slender center. It gives rise to seven branchiostegal rays. Directly in front is the basihyal, a rather broad rectangle having a curved posterior profile but vertical in front, from which springs the enlarged base of the barbel. Between the two basihyals, closely posterior to the origin of the barbel, is a single crescent-shaped supporting bone affording attachment to the controlling muscles of the barbel. Five branchiostegals arise from the basihyal. It equals the epihyal in length. Immediately above the basihyal and articulating along its entire upper profile is the urohyal, quite evenly triangular in shape. From the upper anterior angle extends forward the glosso-

hyal, which is about equal to the urohyal in length but slender and rod-like, and ossified only for its basal two-thirds.

Adult female branchial apparatus: (Fig. 71). The first basibranchial in shape and size closely resembles the urohyal and supports two pairs of slender, fang-like teeth. The second basibranchial is almost twice as long as the first, medianly slender, expanding at both ends. Near the center it also gives rise to two pairs of strongly recurved fangs. The third basibranchial is about as long as the first but much more slender, especially posteriorly. Near the posterior end of this third basibranchial there are faint indications of demarcation into a fourth. Posterior to this there is an unossified cartilaginous mass of connective tissue which from the point of view of physiological function might be called the fifth basibranchial.

Three hypobranchials are plainly indicated. The first is one-third longer than the second, both of which are similar in shape, a narrow median portion connecting expanded ends. The third is only one-half as long as the second and anomalous in both shape and position. Its rather broadly expanded base is attached to the narrow posterior neck of the questionable fourth basibranchial while its anterior end is slightly bifurcated, quite free and directed downward.

There are five ceratobranchials, all slender and rod-like with somewhat enlarged ends. The first and second are normal as to their anterior articulations. The third articulates equally with the attached base of its abnormal hypobranchial. The fourth and fifth articulate with the cartilaginous posterior extension of the basibranchial elements. Each of the first four ceratobranchials at its distal end is attached to a remarkable, slender band of elastic ligament or tissue, in each case about half the length of the ceratobranchial. These ligaments are apparently specialized characters for allowing great distension of the entire branchial apparatus, apparently an aid in swallowing prey of great size. The fifth ceratobranchial, while differing from its fellows in neither size nor shape, ends abruptly with no hint of ligamentous or other continuations.

The distal extremities of the connecting ligaments are connected with the four epibranchials, all of which are slender and rod-like. The first curves slightly forward and ends in a separate short, straight pharyngo-branchial. This element in turn is succeeded by a short but distinct suspensory pharyngeal which lies just below and at one side of the unossified first vertebra. Anteriorly it articulates

loosely with the exoccipital. The third epibranchial shows a slightly curved hook on the posterior side near the upper end, perhaps a disappearing remnant of a former bifurcation. The upper end articulates closely with a pharyngo-branchial of bizarre shape. From the point of articulation a long narrow rod extends upward and anteriorly, articulating with the second pharyngo-branchial. From the ventral surface of the third pharyngo-branchial, close in front of the articulation of the epibranchial, are two to four sharp teeth. Posteriorly the pharyngo-branchial expands into a wide plate and from the lower, posterior angle of this area a small separate ossification gives rise to a cluster of four or five large, downwardly projecting teeth. The fourth epibranchial shows no attachment to a pharyngo-branchial and its bifurcation takes the place of two oppositely directed arms, giving to the whole a shape like a slender tack hammer.

Adult female pectoral girdle: (Fig. 70). Correlated with the total absence of pectoral fins in the adult is a simplified pectoral girdle. The post-temporal is a slender rod of bone slightly bent at its upper end, the whole sloping obliquely forward. It is widely displaced from normal connection with the epiotic, its center lying at the vertical of the articulation between the second and third ossified vertebrae. The distance of this posterior dislocation from its normal point of attachment is almost equal to the length of the entire skull. Below it, and not closely attached, we find the upper end of the supracleithrum which extends in a downward curve to about three times the length of the post-temporal. Close behind its upper head arises the closely welded cleithrum which increases in size in the course of its downward curve until it ends in a forwardly directed knob, its total length being almost twice that of the supracleithrum.

Adult female pelvic girdle: The pelvic girdle consists of a pair of small, triangular, moderately well ossified bones far separated from each other. They lie immediately above the firmly ossified rays of the pelvic fin.

Adult female vertical fins and baseosts: (Fig. 73). The dorsal and anal finrays are all well ossified. The anterior margin of the expanded base of each is prolonged into the pair of short, external spines characteristic of the genus, while there is an exactly similar pair arising from the posterior edge of the base, oppositely directed and

imbedded in the skin. This reinforced base is notched longitudinally and hinges loosely upon one side of a triangular, leaf-like bit of bone. The latter is attached by its opposite angle to the middle of a strong, rod-like baseost which is placed horizontally close beneath the skin. Each baseost touches its neighbors and shows no connection, either direct or indirect, with the vertebral column, while the succession of baseosts and finrays is quite independent of the vertebrae. Hence a continuous supportive rod is formed along the base of each fin which, in the early stages of growth and while still cartilaginous, must serve by the extension of its elements as a plough of sorts, boring forward through the flesh, heading the great anterior migration of the dorsal and anal rays. The triangular, central projections are minute anteriorly, but toward the posterior parts of the fins they become much enlarged and the baseosts are correspondingly more deeply sunken in the flesh. As has been previously explained, the most posterior of the finrays remain crowded together in the same positions as in the larvae; as is to be expected, their underlying baseosts are much shorter than the rest.

Adult female vertebral column: The entire vertebral column and its appendages are well ossified with the exception of the first vertebra. Counting this element and the urostyle there are 78 vertebrae.

As in the young fish the centra are all biconcave and completely lack zygopophyses. Their adult character is manifested in their proportions: all except a few at the beginning and end of the column are considerably greater in length than in maximum diameter, and are much narrowed medially, so that in shape they resemble elongated hour glasses. This distinctive adult shape is exaggerated in direct proportion to the length of the fish (Fig. 61D, E). The most anterior vertebrae are small and relatively deep (2.4 mm long, by 1.6 mm maximum diameter, by .9 mm minimum diameter, in the 267 mm specimen from Bermuda). The maximum size is reached at about the origin of the dorsal fin (4.6 mm by 2.2 mm by .75 mm). This size is maintained until the level of the ninth or tenth anal rays is reached, where the elements become gradually smaller, the last centrum before the urostyle measuring only .6 mm by .4 mm by .16 mm.

The unossified first vertebra (Fig. 71) has no appendages whatever. It is capable of considerable extension antero-posteriorly and its dorsal and ventral halves can expand and contract alternately, so

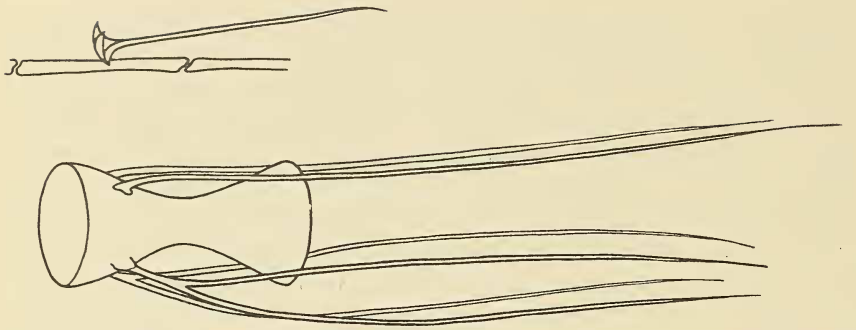


Fig. 73. Tenth dorsal ray, baseost and vertebra from adult female, standard length 267 mm.

that the element actually functions at once as neck and muscle. This makes possible both an up and down movement of the head and a forward thrust, which must increase tremendously the efficiency of the jaws in seizing prey. When we add to the 90 degrees drop of the lower jaw an upward lift of the upper jaw and cranium to an equal extent, the ingestive ability of this genus is seen to be about one hundred per cent.

The second, third and fourth vertebrae, although the centra are somewhat juvenile in size and shape, are firmly ossified. On the anterior dorsal region of each is a pair of well developed neuropophyses having stout neural spines, the latter becoming reduced in size posteriorly. There is no tendency toward fusion to form neural arches. From the base of each neuropophysis arises a long and slender epineural, a little longer than the centrum. Finally, from close to the ventral mid-line of each centrum is a pair of feebly developed parapophyses, each giving rise to a rib, scarcely differentiable from its parapophysis and longer than the epineurals.

Beginning with the fifth element (the fourth ossified vertebra) the neural spine disappears, except for an occasional reappearance as a minute knob, until the several neural arches are formed, far back close to the caudal base. In the absence of the neural spines, the neuropophyses become as slender as the epineurals to which they still give rise (Fig. 73). These backwardly directed structures are now relatively much longer than in the anterior part of the column, being over 2.5 times as long as the centra. Beneath the posterior part of the dorsal fin, however, the neuropophyses become enlarged, while the epineurals are reduced and finally lost with the formation

of the neural arches and their attendant specializations at the end of the fin.

Also beginning with the fifth vertebra long epipleurals, identical in length and diameter with the ribs, arise at the very base of the latter; these two ventral elements do not increase in length to the same extent as the epineurals, being now somewhat shorter than the latter. Like them they conform to the slenderness of the body by curving almost horizontally backwards. The parapophyses increase in size after the tenth anal ray, developing central foramens and a short spine anterior to the ribs and epipleurals. Both of the latter elements gradually shorten, the epipleurals dying out at the fourteenth vertebra before the last, and the ribs at about the tenth, although vestiges remain attached to the specialized parapophyses of the more posterior vertebrae. Corresponding to the lack of neural arches and spines throughout most of the length of the column, haemal arches are formed only behind the end of the anal fin (see below).

Adult female—the posterior part of the vertebral column and the caudal fin: (Fig. 74). Usually the first vertebra to show caudal specialization is the 72nd or sixth anterior to the urostyle segment. This centrum shows a noticeable decrease in length (1.67 mm as compared with 1.88 mm of the two preceding centra), as well as the first appearance of a neural arch with a single, strong, median neural spine. Posterior to the triangular neural arch there is a similar bony structure which extends from the base to the tip of the arch. It is fused with the left base and the tip of the neural arch. Between the upper two-thirds of the structure there is a clear unossified area. This is the only dorsal appearance of such a double structure in the posterior half of the body. It could easily be passed by as an abnormality or as evidence of a pseudo-double vertebra, but this extra support and strengthening appears where it is most needed in a gap free of fin rays midway between the last posterior dorsal ray and the first anterior caudal raylet. There is also an anterior median projection from the dorsal side of the neural spine.

There are two separate haemal bases, each with irregular narrow spines. The left one extends posteriorly to the haemal process of the following centrum while the right one extends only midway. A narrow ridge of bone with several teeth-like serrations extends the full length of the haemal base. At the distal end this broadens into

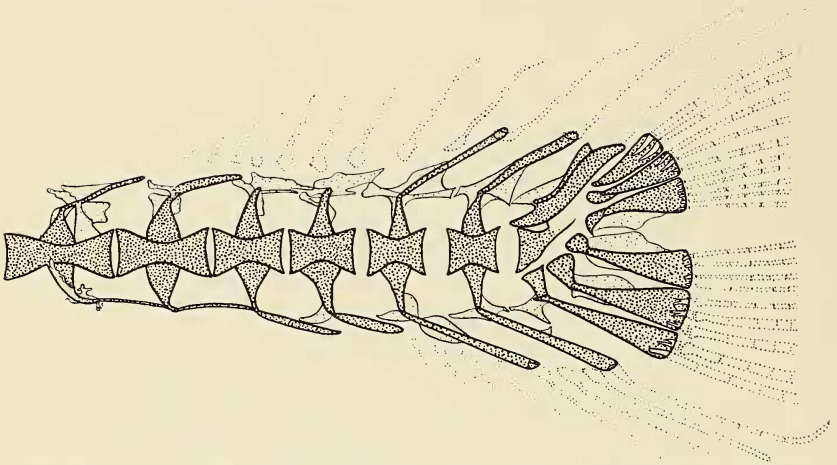


Fig. 74. Posterior vertebral column and base of caudal fin in adult female. (× 8.5).

two prong-like projections, one directed dorsally and the other ventrally.

The centrum of the 73rd, or the fifth vertebral process anterior to the urostyle, is situated directly below the first caudal raylet. The general form is similar to the 72nd. The centrum is shorter (1.34 mm) than the preceding but the depth is the same (.75 mm at the articulating edge and .32 at the center). The neural base is a little longer and has small median anterior and posterior projections at its distal end and a short prong which divides into two lateral barbs. The strong neural spine extends backward to the anterior projection of the following process.

The haemal process of the 73rd vertebra is very like the preceding but greatly simplified with only a hint of extraneous structures and almost symmetrically paired spines that extend to and touch the tip of the next posterior haemal process. The 74th and 75th vertebrae are alike in every way but details. The posterior centrum is shorter than the preceding, the 74th being 1.08 mm and the 73rd .91 mm long. The neural spines of both have developed into broad flat bones that occupy most of the area between the ray bases and the tip of the neural arch. There are anterior and posterior projections from the spines which extend as far as similar projections from adjacent structures. The haemal spines have become strong and dagger-like and each touches the anteriorly directed basal

projections of the next posterior spine. The first haemal arch appears in the 74th process.

The 76th and 77th vertebrae are almost identical part for part, dorsal and ventral. The lengths of the centra (.81 mm) are the same. The distances between the centra become wider as we approach the urostyle.

Prolonged neural and haemal spines appear for the first time in the 76th and 77th vertebrae. These extend into the caudal contour and form a definite part of this structure. Each spine is a strong, long, flat bone, which becomes gradually broader at the distal end.

The urostyle is ossified only in the anterior part which resembles an unspecialized half centrum. The upturned posterior end has only a fragmentary patch of bone scattered over the dorsal and ventral surfaces as far as the position of the third hypural. No separate segments can be detected in the clear, unossified, tapering end of the urostyle. This is a distinct contrast to the urostyle development in some of the shallow-water Isospondylids where ossification is dense and several separate segments are prominent in the upturned end.

The entire dorsal surface of the urostyle is covered by a broad, saddle-shaped neural structure that extends posteriorly into the caudal contour. There is one well defined epural that extends along the dorsal surface of this bone. At its proximal end it appears to be imbedded in the neural structure that covers the urostyle.

There are six hypurals, three dorsal and three ventral to the median axis. These bones are elongate, flattened, and triangular. The first hypural on the ventral surface is the longest and the second is the broadest of the six. Both the arch and the prolonged spinal part of each hypural becomes shorter in each successive dorsal bone. The remains of the haemal arch of the sixth hypural on the dorsal surface is rudimentary. None of the arches are attached directly by ossified structure to the urostyle. There is a clear unossified area between the arches and the urostyle. The distal ends of the three dorsal and the three ventral hypurals broaden out and form two almost solid fan-like units. The wide gap between the dorsal and ventral units is partly solidified by two, thin, median wings of bone. Attached to and extending between the tips of the two central hypurals is a prominent ligamentous band.

In the external and internal characters the ventral half of the

caudal fin is more developed than the dorsal half. The longest ventral rays extend three millimeters or more beyond the dorsal rays and are stouter and more heavily ossified. The ventral hypurals are longer and heavier than the dorsal hypurals.

The sequence of raylets and rays, counting from the anterior dorsal around to the ventral is 14 + 10 + 10 + 7 = 24/17. The first dorsal and ventral rays are rudimentary and entirely embedded in the tissues, and in uncleared specimens both are invisible. The first anterior dorsal ray and the first and second anterior ventral rays are only slightly more developed than the raylets that immediately precede them, but the rays possess the character that distinguishes them from raylets, that of cross bars.

There are four strongly ossified ventral rays, the third, fourth, fifth and sixth—the last three of which are bifid for the posterior half of their length.

The first ventral ray has a single cross bar near its tip which is in line with the first bar at the basal end of the second ray. This has six bars commencing half way between the base and the tip. The second ray is a little broader and twice the length of the first and more heavily stained than any of the preceding rays or raylets. Posterior to the third bar the ray becomes thread-like and diminishes to less than half the width at its basal end.

The first and second ventral rays are attached to the second, or last, prolonged haemal spine which forms part of the caudal contour.

There are three strongly ossified and elongated dorsal rays, the second, third and fourth. In size none are as stout as the corresponding ventral rays. The first anterior dorsal ray is twice the length of the preceding raylet, half the length of the following, or second ray, and has three or four cross bars.

Adult Female Digestive System: (Figs. 62F, 75). The alimentary canal measures 56 per cent of the standard length, slightly more than in the transitional adolescent. This relative increase in length is caused principally by the elongation of the oesophagus, which in turn is due to the reduced size of the head. The black stomach is short compared with its size in many Stomiatoids, such as *Stomias* and the more elongate Melanostomiatids. It is contained 6.1 times in the standard length and ends just short of the plane of the pelvic fins. The two caeca are well developed, the more posterior being the larger and about equal in length to the pyloric canal joining stomach

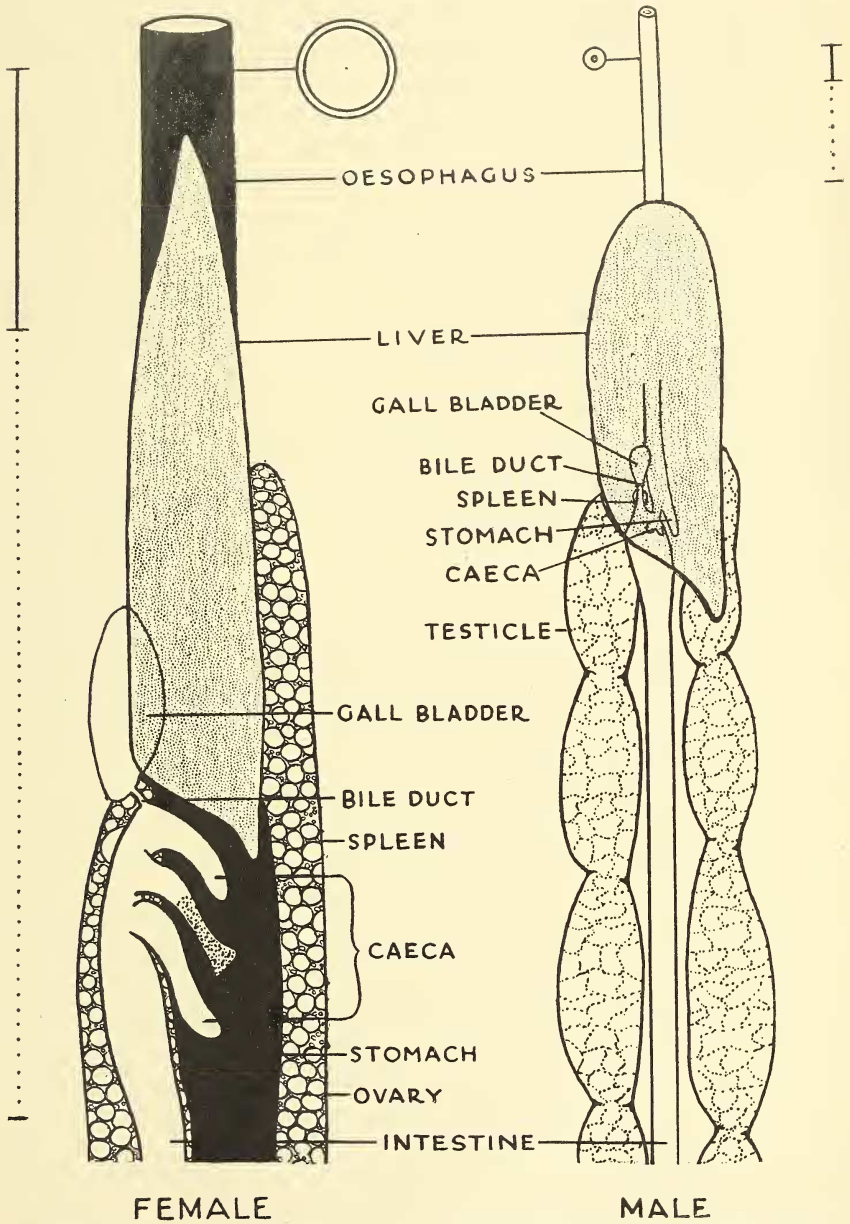


Fig. 75. Ventral views of anterior one-quarter of digestive and reproductive organs in breeding adults. Left, female, standard length 267 mm; right, male, standard length 35 mm. The relative length of the alimentary canal in the two specimens is shown by the straight lines, the portion figured being solid, the remainder broken.

and intestine. The liver is single-lobed and almost as long as the oesophagus, relatively much longer than in any preceding stage. It broadens slowly from its anterior point beneath the oesophagus until the posterior portion extends upwards around the oesophagus and completely surrounds it. The left side of its terminal edge is drawn out into an attenuated tip. The pancreas is a thin layer of tissue lying between the anterior half of the liver and the oesophagus, scarcely distinguishable in the preserved specimen from the substance of the liver. The deflated gall bladder is almost a third as long as the liver, lying above that organ's posterior right end. The bile duct is even shorter than in the transitional adolescent, the bladder being very close to the pyloric region. The spleen lies above and behind the posterior end of the bile duct. The intestine is perfectly straight and smaller in diameter than the oesophagus.

The following measurements were taken: Length of alimentary canal 150 mm; oesophagus length 30 mm; oesophagus breadth 3 mm; stomach length 44 mm; longest caecum 5 mm; maximum liver length 25 mm.

Adult Female Reproductory System: (Fig. 75). The left ovary begins 13 mm behind the mandibular angle; it is 135 mm long with a maximum breadth of 4 mm and a maximum thickness of 2 mm. The right is similar except that it originates 9 mm behind the left. Both are broadest toward the middle of their lengths, tapering gradually anteriorily and posteriorly to rounded ends. The eggs have been already described.

Adult Male Trawling Data: The external characters are based upon the following specimen: Department of Tropical Research No. 16,645; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 770; July 4, 1930; 12 miles south of Nonsuch Island, Bermuda; 700 fathoms; Standard length 38 mm.

Adult Male Measurements and Counts: Total length 41.6 mm; standard length 38 mm; depth, maximum, at dorsal origin, 1.9 (in length 20); depth, minimum, behind anal end, 1.1 (in length 34.6); head 3.9 (in length 9.7); eye 1.1 (in head 3.6, in length 34.6); snout 1.1 (in head 3.6, in length 34.6); dorsal origin to caudal base 24 (in length 1.6); anal origin to caudal base 11 (in length 3.5); dorsal rays 62; anal rays ca. 40; caudal rays XII + 10 + 9 + VII; postorbital 1.4 (in head 2.8, in length 27.1); serial photophores: branchiostegal organs 13; lateral series 49 (last 4 above anal); ventral series, I–A 58 (last 5 above anal), A–C 20; penis 1.3 (in eye .8).

Adult Male External Characters: (Figs. 47; 50F; 57A, B; 66). In many ways this adult fish is a typical post-larva: The general color is dark brown, not brownish black as in the adult female. The greatest depth is toward the middle of the body, not at the shoulder, and the caudal peduncle is relatively deeper than in the female. The head is more than a third longer in proportion to the length than in adult females, while the eye, although perfectly round, firmly fixed in the socket and having no trace of stalk, is between one-third and one-half again as large as the eyes of adult females. The snout also is somewhat longer and exceedingly convex, while the female snout tends to concavity. The lower jaw is strongly curved and projects noticeably beyond the upper. The premaxillary is relatively no longer than in the larva, although it has the upward anterior projection typical of this group of fish; the maxillary, although showing an increase in length in the male since transitional adolescence is noticeably shorter relatively than in the female. Both upper and lower jaws are completely edentulous.

The pectoral nubbin has entirely vanished and there is no sign whatever of pelvic fins. The dorsal and anal rays fall within the range of the adult female counts, but are soft and relatively close together; the typical inter-ray spines of *Idiacanthus* are present. The shape of the caudal fin is the same as in the female, and the numbers of elements identical, but the fin is contained 10.6 times in the standard length instead of about 33.3—that is, the fin is relatively more than three times as long as in the female, a character normally indicating immaturity throughout this group.

The enormous cheek light is much longer than the eye; a narrow subocular portion, evidently fused with the antorbital, extends flush with the anterior border of the eye; behind the eye the organ is enormously swollen, bounded dorsally by the horizontal though the middle of the eye and ventrally by the maxillary. Its maximum length is 1.4 mm, while the theoretical maximum depth to which it might be opened is .7 mm. In this and all of the other adult male specimens in the collection, however, the luminous center is never more than half exposed, always directed downwards. There is no trace of a barbel. The serial photophores are well developed, violet in the fresh specimen. There are, however, two or three organs fewer in the lateral series than in the minimum counts for adult females, exactly as is common among post-larvae.

Corresponding to the luminous material at the bases of the teeth in the adult female, there is a complete line of luminescence within each of the transparent jaw bones of the male. This is especially noticeable in the mandible. There is no luminous line beneath the postorbital light, since the latter organ is pressed against the maxillary. On the body a double series of luminous patches alternates with the photophores as in the female, the lower row being the stronger. There is an immense quantity of luminous granular matter in the webbing of the dorsal and anal fins, along their bases and on the caudal fin. The caudal luminous organs are essentially the same as in the female, except that the dorsal, peduncular organ is scarcely differentiated from the luminous matter between the dorsal caudal raylets, while the finger-like process of the organ of the lower caudal lobe is rudimentary.

There are no lesser light organs on head or body.

Adult Male Osteology: The adult male is extremely difficult to characterize with any exactitude. Some of the osteological elements cannot be distinguished from those of the adult female, while others show various degrees of interrupted development and some are almost wholly larvoid.

The degree of ossification, while very slight at the best, varies so greatly that no two males show it to the same extent. Of half a dozen specimens subjected to the clearing and staining process only three absorbed any stain whatever, and in these it was confined entirely to the jaw apparatus and its supports, to the region of the intromittent organ, and to the caudal fin. The particular areas of ossification in these specimens, listed in order of intensity of stain, are as follows: Mandibular symphysis; premaxillary; maxillary, mandible; first anal rays; base of caudal rays (in two out of three cases); parasphenoid; preopercle; cleithrum; junction of opercle and hyomandibular; upper part of hyomandibular; pharyngeals; pterotics and epiotics; vertebrae in central third of body. In the last three or four areas mentioned the stain is always exceedingly light.

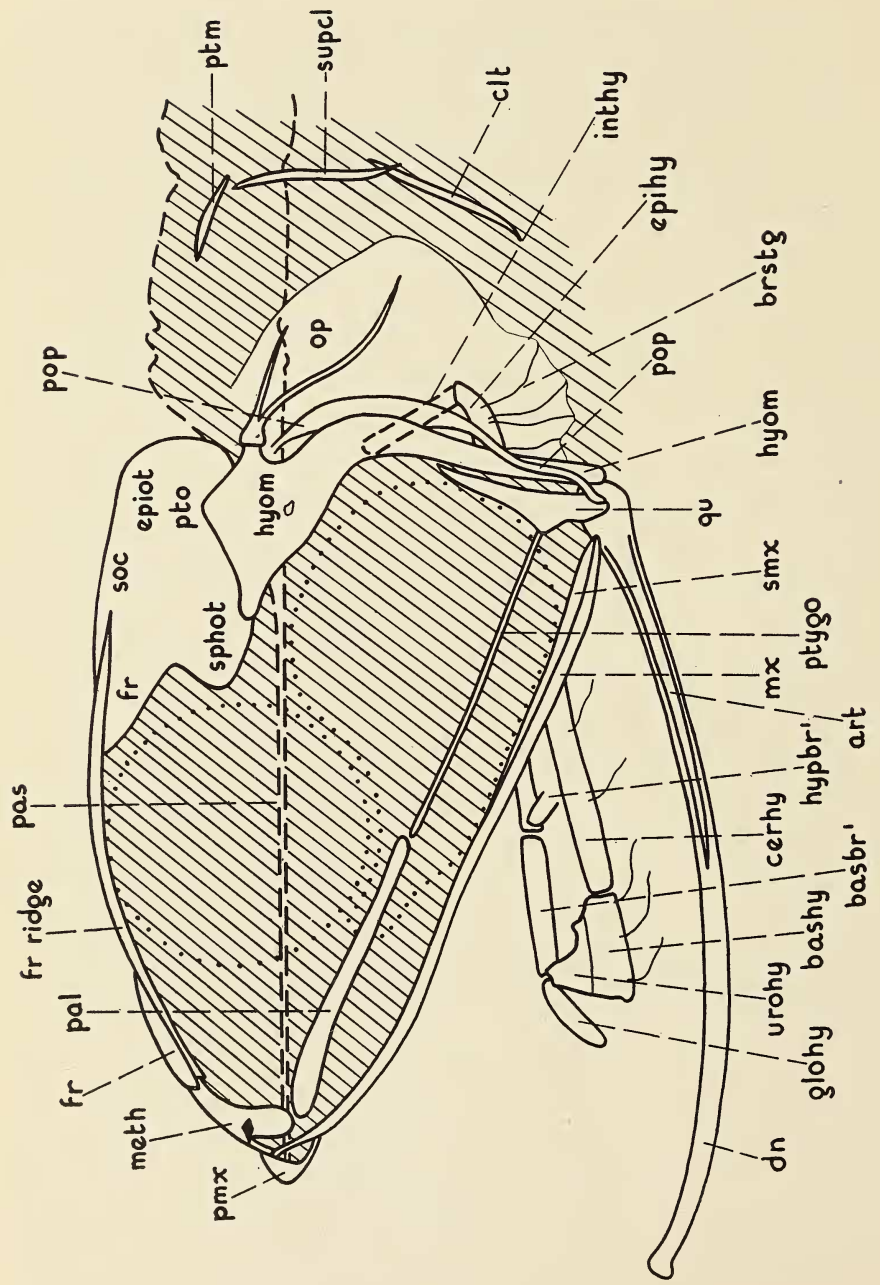
This variation in the amount of bony tissue indicates either that the full breeding condition in this sex is assumed at different stages of development in various individuals, or else that such characters as the degree of ossification continue development after the fully adult condition is reached.

The general conformation of the bones in all adult males is, however, very similar in all specimens.

Adult male skull: The cranium viewed from above differs only slightly from that of the adult female. It is especially interesting that the limits of the various bones are even less distinct than in the full-grown female. The chief distinction is the rudimentary condition of the frontal ridges and mucous tunnels. Whatever function these subserve in the adult female, they are apparently useless in the opposite sex.

Adult male palato-pterygoid arcade: (Fig. 76). The hyomandibular is much more generalized and less definite in shape than in the female. The three expanses of the head of the bone are little more than blunt protuberances with, of course, perfect articulation with the pterotic and the main ossification of the opercular. The elongated body of the hyomandibular shows a very striking immature stage in the general direction of the suspension of the jaw. Instead of continuing straight backward almost paralleling the pterygoid as in the adult female, it describes a nearly right-angled curve downward and forward to its articulation with the angle of the jaw. The quadrate is relatively smaller in this sex and is not closely applied to the hyomandibular, but follows its upward and backward direction lying at right angles to instead of paralleling the pterygoid. The obliteration of the internal flange of the head of the hyomandibular together with the great circle described by its body and the quadrate not only reflects a decided larvoid character but also permits of a large free area at the side of the head, even larger than the eye socket itself, which houses the huge light organ of the male. Therefore this same curve of the hyomandibular reflects at one time very primitive and very specialized conditions. No trace of the metapterygoid is visible, its obliteration being a further adaptation in making room for the cheek light. The secondary upper jaw is not very unlike that of the adult female except that the palatine is almost equal to the pterygoid in length and while stouter throughout lacks the anterior dilation.

Adult male jaw apparatus: (Fig. 76). In the upper jaw we have conditions almost wholly larval, the premaxillary being very small, for although it has the upwardly directed, bony cone found in the adult female, laterally it hardly reaches farther than the head of the palatine. As in the larva the entire profile of the edge of the upper jaw is formed by a slender, undulating maxillary with the typical supramaxillary in place. The lower jaw, an evenly curved, slender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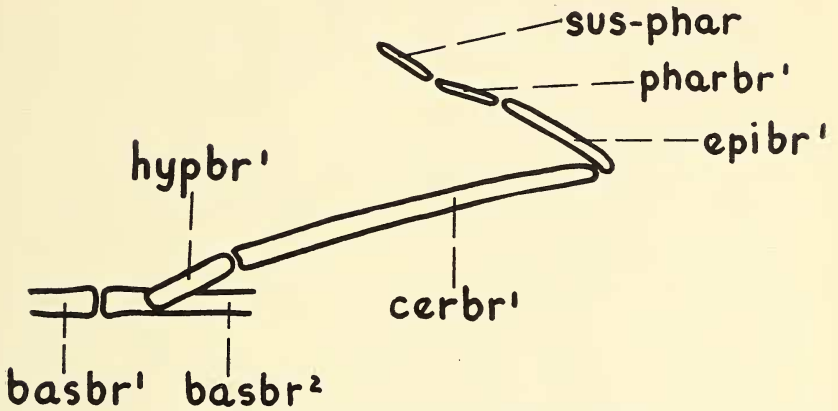


Fig. 76. (Left) Elements of head of adult male, lateral view. (× 28).
Fig. 77. (Above) First branchial arch of adult male.

rod, projects conspicuously beyond the premaxillary. The articular is normal in position and extent. In the most ossified individuals the anterior halves of both jaws show strong deposits of bone, gradually lessening posteriorly. The jaws and the entire oral cavity are completely edentulous.

Adult male opercular bones: (Fig. 76). Three elements only are recognizable in this assemblage. The opercle itself is supported as in the adult female by two centralized ridges and by the preopercle. The latter follows the general outline of the hyomandibular but, as in very young specimens, is unattached to that bone and very slender and sinuous ventrally. The posterior branchiostegal rays are long and strong and continue the webbed outline of the opercle.

Adult male hyoid arch: (Fig. 76). In the hyoid arch the elements are far less specialized in shape than in the adult female. The glossohyal is relatively larger and thicker, the urohyal smaller, while the posterior branchiostegal rays are more scattered than in the adult female.

Adult male branchial apparatus: (Fig. 77). The branchial arches are exceedingly primitive and absolutely lack the specialized extensory power seen in the corresponding structures of the adult female. There is no hint of the extremely elastic ligaments between the articulations of the ceratobranchials and epibranchials, while the three superior elements, the epibranchials, pharyngo-branchials and the suspensory pharyngeal, are all very short, cartilaginous rods with

no hint of the elongate characters of the adult female. And so, correlated with the edentulous jaws, we find the branchial arches wholly lacking in the power to stretch wide apart and so admit passage for food of any size.

Adult male pectoral arch: (Fig. 76). The post-temporal, like that of the adult female, is widely separated from the epiotics. The supracleithrum and cleithrum are very distinct, overlapping only at their extreme tips in a manner quite different from the close association of these bones in the adult of the opposite sex. There is no trace of either pelvic girdle or pelvic rays.

Adult male vertical fins and baseosts: Only the anterior half of the anal fin is ever ossified. Its specialized first rays are subsequently described in connection with the reproductive system. They alone have their bases simple and almost unexpanded, the remaining dorsal and anal rays each having two pairs of basal spines—one external and one internal—exactly as in the female. In both fins the baseosts, so strongly developed in the female, are visible only as slivers of cartilaginous tissue, although longitudinally placed as in the opposite sex.

Adult male vertebral column: The vertebral column is not completely segmented. Differentiation of the vertebrae is only indicated in the opercular region and apparently occurs in the extreme posterior caudal area last.

The only trace of ossification in the column in any of the specimens occurs, in approximately the center third of the body, ending at about the level of the intromittent organ. Here there is a light deposit on the dorsal and ventral, and along the articulating surfaces, of the centra.

The centra (Fig. 61d) are not elongated and spool-shaped as in the adult female, but instead the dorsal-ventral depth is greater than the length, and the shape, viewed laterally, is rectangular. The dorsal and ventral surfaces in the midportion of the body are even slightly convex, so that the centra of the adult male may be said to be actually more larvoid than those of the larvae themselves. This is largely explained by the shrinkage in the length of the fish which takes place during adolescence. A centrum, toward the middle of the body of a specimen 32 mm in length is .59 mm long and .82 mm in maximum diameter.

The vertebral appendages, although completely unossified and

comparatively short, are exactly similar to those of the female in form and relative positions.

Adult male—end of vertebral column and caudal fin: (Fig. 78). As in the adult female, distinct caudal specialization occurs in the area of the sixth and fifth vertebrae anterior to the upturned urostyle. Here, the neural and haemal processes become heavier, longer and directed more posteriorly. Unlike the adult female, all the processes in the male are simple and rod-like. None show bone deposit. The two posterior neural and haemal spines are enlarged and prolonged and are the first to form a definite part of the posterior caudal contour.

Only the anterior part of the specialized neural structure, so prominent in the female along the dorsal surface of the urostyle, can be determined. The single epural is present and occupies some of the area between the urostyle and the last prolonged neural spine.

There are six hypurals, generalized in shape and lacking all extraneous structures. Only in the first hypural is the haemal arch defined. The distal ends of the three dorsal hypurals form a solid unit for the last fourth of their length. In a 42 mm specimen the ventral hypurals, as well as the dorsal, are fused distally.

The sequence of raylets and rays, counting from the anterior dorsal element is typically $11 + 10 + 11 + 5 = 21/16$. Slight ossification is shown at the bases of the rays in two of the specimens.

Adult Male Digestive System: (Figs. 63F, 65F, 75). As in the male adolescent and transitional adolescent, the gut of the adult is three-fifths as long as the fish or relatively almost equal to that of the adult female. In the male, however, all portions of the digestive system are, with the exception of the liver, degenerated to varying degrees. The oesophagus is very narrow with a thread-like bore and is shorter than before, as the liver, although no longer, now completely overlaps the pyloric organs ventrally; the stomach is the same minute, white appendage found in earlier stages; the caeca are rudimentary and no distinct pyloric canal is developed; the gall bladder and bile duct are both much reduced; and the intestine is only slightly broader than the oesophagus. The liver is no longer than in younger specimens, but it is broader, completely surrounding the oesophagus with the edges of the lobe meeting dorsally. As in the female the pancreas is an inconspicuous layer of tissue between the anterior half of the liver and the ventral side of the

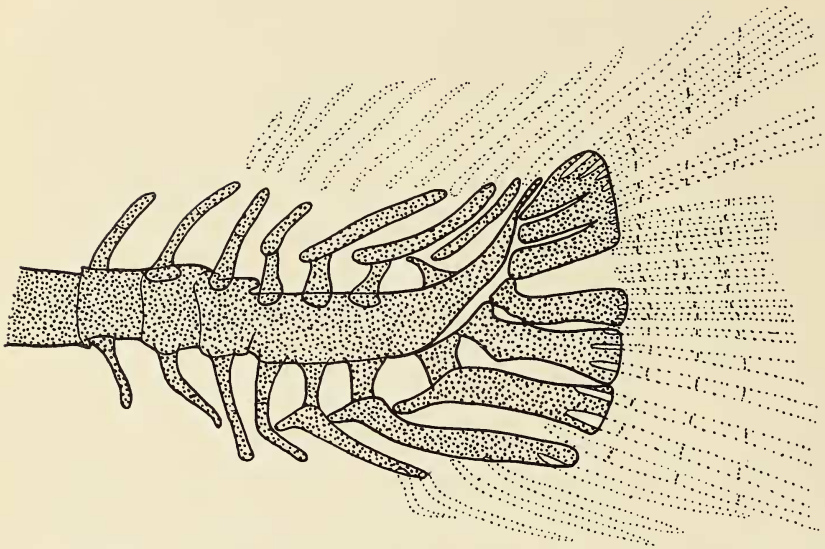


Fig. 78. Posterior vertebral column and base of caudal fin in adult male. (× 34).

oesophagus. The spleen is slightly reduced. Compared with the transitional adolescent male the reductions of the diameter of the gut and of the size of the gall bladder are the greatest changes. The only developmental reduction held in common with the female is the shortening of the bile duct. Pigment is lacking from the male coelom with the exception of a small and variable quantity on the oesophagus. Its most constant form is an elongate, broken patch about half the length of the oesophagus on its anterior dorsal surface.

The posterior end of the intestine passes close to the sperm duct, but is quite separate from it. The anal papilla appears as an anterior swelling at the base of the intromittent organ.

Adult males vary somewhat in the size of stomach, caeca and gall bladder, all of these organs being almost non-existant in several of the specimens examined. The following measurements show typical proportions and were made upon a male 32 mm in length, in full breeding condition: Gut length 19.3 mm; oesophagus length 2.1; oesophagus breadth .11; stomach length .34; stomach breadth .06; caecum .15; liver length 1.8; gall bladder length .17; diameter of intestine, anterior portion, .13; diameter of intestine, posterior portion, .08.

Adult Male Reproductive System: (Figs. 75, 79). The testicles are relatively as long as the ovaries of the female, the longer (left side) beginning at a point about one-tenth of the distance from throat to anus. In the male this falls slightly behind the middle of the liver. Both right and left organs extend clear to the end of the body cavity. In section the testicles are circular with maximum diameters three times or more that of the intestine. Each organ is divided into at least fourteen or fifteen unequal divisions by constrictions and small, single pleats. These vary in position and sometimes in number and distinctness on the two sides of the same fish. The testicles are entirely covered by a continuous network of pigmented strands, the fundamental pattern of which consists of transverse bands connected by longitudinal cross-bars. The following measurements were made upon the 32 mm male mentioned above: Left testicle length 17 mm; maximum diameter .38; minimum diameter (excluding constrictions) .26.

Immediately anterior to the vertical from the anus both testicles converge to form a common sperm reservoir which extends dorsally close to the vertebrae and posteriorly to the vertical from the seventh anal ray. From the ventral side of this reservoir, a little before the middle of its length, a broad duct leads down through the intromittent organ, ending in a pore at the anterior side of its swollen tip.

The intromittent organ is about equal in length to the diameter of the eye, dark brown in color, and extending diagonally downwards and backwards against the first anal rays. The latter are very definitely modified for its support: The first ray is always flattened throughout its length with a triangular expansion at each side along its upper and median portions. This ray is sometimes highly ossified, as are the several subsequent rays, although less strongly. The second and third rays usually pass to the right of the intromittent organ and have their distal portions securely attached to the posterior side of its tip, while the fourth and fifth rays similarly support the left side. The sixth ray is linked closely to the group by webbing. The positions of the individual rays vary somewhat on different specimens, but the general plan is always the same. There is no trace of basal spines in connection with any of these modified rays. Due to the intimate connections between rays and intromittent organ and the consequent limited movement of the latter, its func-

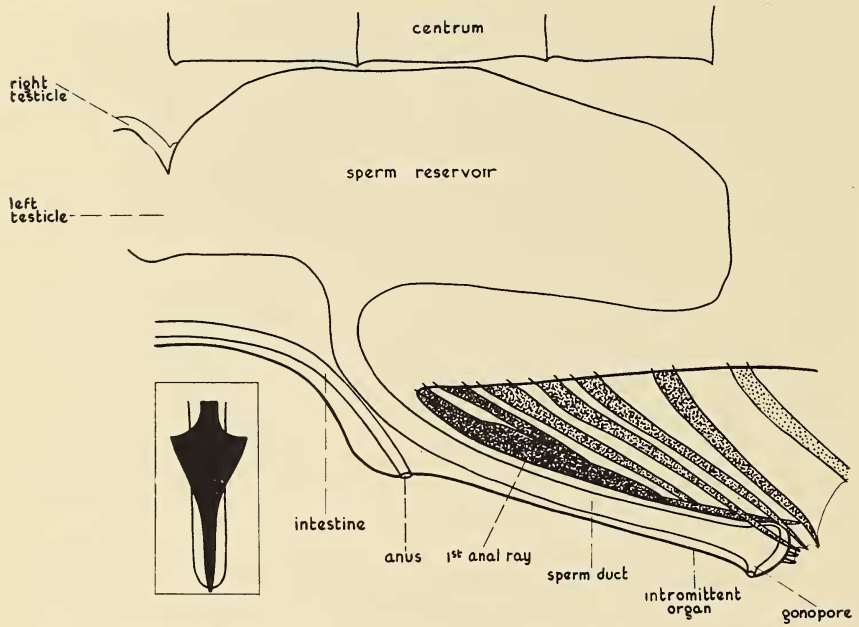


Fig. 79. Sagittal section through intromittent organ and surrounding region of adult male. The shaded areas indicate various degrees of ossification in the anal rays. (× 60). Inset: posterior view of first anal ray and intromittent organ.

tioning as a penis during any sort of internal fertilization seems very questionable. This organ is analogous but not homologous with those found in many fresh-water oviparous fish.

Beginning with the seventh, the rays are slightly or not at all ossified.

Ecology

Vertical and Seasonal Distribution: The vertical, monthly and yearly distribution of the Bermuda specimens of *Idiacanthus fasciola* is shown in Fig. 80. Two nets, drawn in September at 100 fathoms, contained eleven of the thirteen larvae in the collection. The rest of the fish, at all stages of development, were caught between 500 and 1000 fathoms, at a mean depth of 681 fathoms. The diagram at the right of the map (Fig. 48) indicates this distribution in graphic form. As in the case of numerous other genera of deep-sea fish taken by the Bermuda expeditions, *Idiacanthus* (except larvae) was never caught off Bermuda at the comparatively

shallow depths from which it has been often reported in other parts of the world. From the Bathysphere I saw an adult female at 200 fathoms (Beebe, 1930, p. 222).

The accompanying diagrams (Fig. 81) indicate the seasonal distribution of the species, divided into groups according to age and sex, throughout the major portion of the three-year trawling season. (Too few deep-sea nets were drawn in April and October to furnish comparable data for these months, and during the winter it has so far been impossible to do any trawling whatever.) The upper chart shows the actual numbers of individuals taken; in the lower are the numbers that theoretically would have been taken had as many nets been drawn every month as during September.[1] But in both charts the proportionate sizes of the various groups are in general the same: Through the months adult males formed the most numerous class and were distributed fairly evenly during the period. They were, however, most plentiful in the summer months, and adult females and larvae were taken only in August and September. Young specimens of both sexes were less numerous than the adult males, but were similarly scattered through the season; their month of maximum concentration, however, as with the larvae, was September. From this it may be inferred that there is a chief breeding season in late summer.

SOCIABILITY: The larvae undoubtedly school, as shown by the occurrence of the youngest stages in groups of three and eight individuals, respectively. Also, two post-larval males were taken together and, in another case, a post-larval female with an adolescent of the same sex. In each of five other nets adult males were taken two at a time. The latter cases may have been accidental, as it seems likely were the six other pairs of fish of very dissimilar growth stage: in each of the latter the pair consisted of a post-larva or transitional post-larva of either sex caught with a transitional adolescent or adult female. The one breeding female came up with a male post-larva. No evidence was found on adults of either sex of parasitic habits in the male.

ABUNDANCE: *Idiacanthus fasciola* is fairly common among the deep-sea fishes taken off Bermuda. One or more specimens occurred in nine per cent of all of the nets drawn between 100 and 1000 fathoms, the limits of its vertical distribution in this locality.

[1] See Zoologica, Vol. XVI, No. 1, p. 7.

Fathoms	April			May			June			July			Aug			Sept			Oct			Total		
	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931
100																		11						11
																	11						11	
200																								
300																								
400																								
500	2						2		1		2				3		3	2				4	5	5
		2						3			2			2			5						14	
600	3				1		3		1	1	3	1	2		6	2	5	6			2	11	9	16
		3			1			4			5			8			13			2			36	
700	1			4	3		5	3	3	3	6		1		1	5	4	2				19	16	6
		1			7			11			9			2			11						41	
800	1			1			1			3	1		1		1	4	2					11	3	1
		1			1			1			4			2			6						15	
900				1			1						2		1			3				4		4
					1			1						3			3						8	
1000							1								2		1					1	1	2
								1						2			1						4	
Total	7			6	4		13	3	5	7	12	1	6		13	11	15	24			2	50	34	45
		7			10			21			20			19			50			2			129	

Fig. 80. *Idiacanthus fasciola* Peters. The vertical, monthly and yearly distribution of the specimens taken by the Bermuda Oceanographic Expeditions.

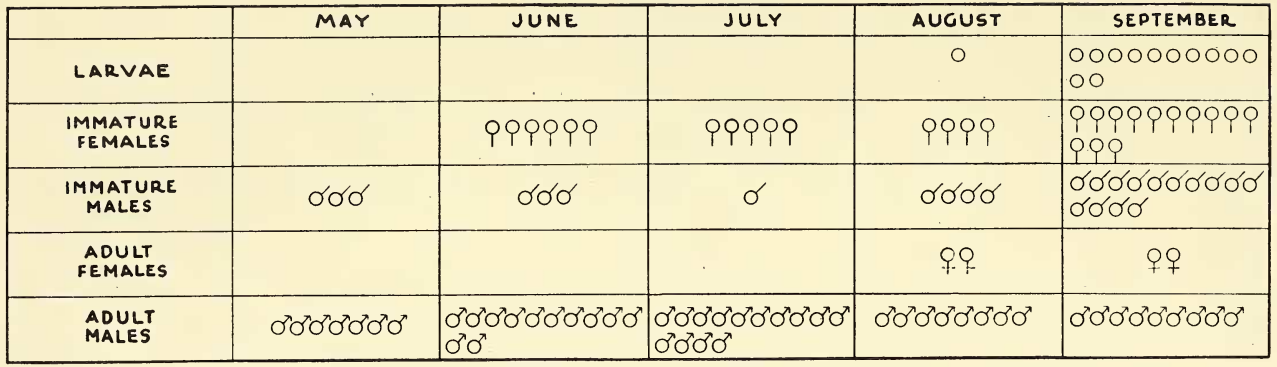
FOOD: The stomachs of ten of the largest females, all transitional adolescents and adults, were examined, and of these three contained remains of fishes. One only was recognizable, a *Diaphus* sp., measuring about 61 mm in length and taken from an *Idiacanthus* of 255 mm. In the intestines of all of the specimens there was a smaller or larger amount of unrecognizable material.

The intestines of several larvae and post-larvae of both sexes contained diatoms and the remains of minute crustacea. Brauer[1] also found crustacea in his specimens of *Stylophthalmus*.

Due to the degeneration of the digestive system all males subsequent to the post-larval stage have the alimentary tract entirely empty.

ENEMIES: *Idiacanthus fasciola* has not yet been found in the stomach of any creature, nor have parasites been observed. It is of interest to note, however, that the type of *I. niger* and one other

[1] Brauer 1906, p. 68.



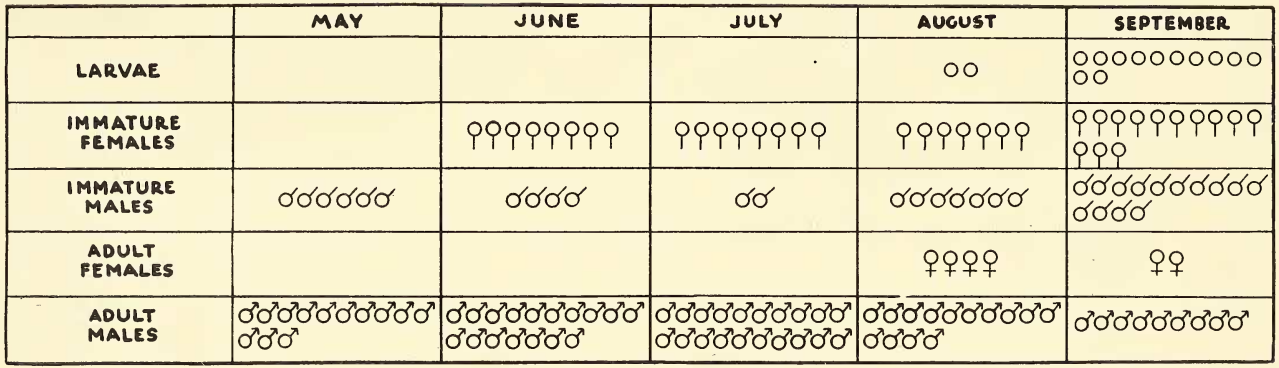


Fig. 81. Diagrams indicating the seasonal distribution of the growth stages of *Idiacanthus fasciola* off Bermuda, throughout the major portion of the three-year trawling season. The upper chart shows the actual numbers of individuals taken; the lower, the numbers that theoretically would have been taken had as many nets been drawn every month as during September. (See Zoologica, Vol. XVI, no. 1, p. 7).

specimen of that species were taken off New Zealand in the stomachs of gropers (*Polyprion oxygeneios* and *Polyprion americanus*)[1]

Study Material

The following list gives the catalogue number, net, depth in fathoms, date, length and growth stage of each specimen of *Idiacanthus fasciola* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described on page 5 of the present volume (Vol. XVI, No. 1).

No. 8,733; Net 6; 600 F.; April 5, 1929; 129 mm. Trans. Adol. ♀
No. 8,760; Net 15; 500 F.; April 12, 1929; 35 mm; Adult ♂
No. 8,820; Net 23; 600 F.; April 15, 1929; 35 mm; Adult ♂
No. 9,525; Net 31; 500 F.; April 24, 1929; 35 mm; Adult ♂
No. 9,598; Net 39; 600 F.; April 25, 1929; 38 mm; Adult ♂
No. 9,609; Net 40; 700 F.; April 25, 1929; 39 mm; Adult ♂
No. 9,716; Net 53; 800 F.; April 30, 1929; 33 mm; Adult ♂
No. 9,756; Net 65; 700 F.; May 4, 1929; 38 mm; Adult ♂
No. 9,767; Net 66; 800 F.; May 4, 1929; 32 mm; Adult ♂
No. 9,827; Net 79; 700 F.; May 8, 1929; 34 mm; Adult ♂
No. 10,023; Net 101; 700 F.; May 14, 1929; 39 mm; Adult ♂
No. 9,993; Net 104; 700 F.; May 15, 1929; 44 mm; Adult ♂
No. 24,060; Net 144; 900 F.; May 31, 1929; 38 mm; Adult ♂
No. 10,323; Net 148; 700 F.; June 1, 1929; 42 mm; Adult ♂
No. 10,352; Net 153; 700 F.; June 8, 1929; 38 mm; Trans. Adol. ♂
No. 10,476; Net 170; 500 F.; June 15, 1929; 48 mm; Trans. Adol. ♀
No. 10,508; Net 176; 500 F.; June 17, 1929; 36 mm; Adult ♂
No. 10,520; Net 177; 600 F.; June 17, 1929; 30 mm; Trans. Adol. ♂
No. 10,603; Net 188; 600 F.; June 19, 1929; 34 mm; Adult ♂
No. 10,610; Net 189; 700 F.; June 19, 1929; 33 mm; Adult ♂
No. 10,838; Net 207; 700 F.; June 22, 1929; 75, 125 mm; Trans. Adol. ♀
No. 10,966; Net 222; 1000 F.; June 25, 1929; 60 mm; Trans. Adol. ♀
No. 11,076; Net 233; 600 F.; June 28, 1929; 90 mm; Trans. Adol. ♀
No. 11,087; Net 235; 800 F.; June 28, 1929; 28 mm; Trans. Adol. ♂
No. 11,088; Net 236; 900 F.; June 28, 1929; 40 mm; Adult ♂
No. 11,535; Net 293; 700 F.; July 12, 1929; 33 mm; Adult ♂
No. 11,542; Net 294; 800 F.; July 12, 1929; 37 mm; Adult ♂
No. 11,577; Net 299; 700 F.; July 13, 1929; 38 mm; Adult ♂
No. 11,634; Net 305; 600 F.; July 16, 1929; 37 mm; Adult ♂
No. 11,725; Net 313; 800 F.; July 22, 1929; 35 mm; Adult ♂
No. 11,755; Net 317; 700 F.; July 23, 1929; 35 mm; Adult ♂
No. 11,811; Net 324; 800 F.; July 24, 1929; 31 mm; Trans. Adol. ♂
No. 12,135; Net 356; 700 F.; Aug. 9, 1929; 49 mm; Post-larva ♀
No. 24,147; Net 369; 800 F.; Aug. 14, 1929; 45 mm; Post-larva ♀

[1] Regan 1914, p. 14; Waite, 1916, p. 55; Archey 1922, p. 295.

No. 12,342; Net 374; 600 F.; Aug. 15, 1929; 33, 37 mm; Adult ♂
No. 12,405; Net 382; 900 F.; Aug. 16, 1929; 16 mm; Larva
No. 12,586; Net 394; 900 F.; Aug. 19, 1929; 33 mm; Adult ♂
No. 12,963; Net 411; 700 F.; Sept. 3, 1929; 49 mm; Adolescent ♀
No. 13,063; Net 418; 700 F.; Sept. 4, 1929; 46 mm; Post-larva ♀
No. 13,397; Net 453; 600 F.; Sept. 10, 1929; 161 mm; Trans. Adol. ♀
No. 13,419; Net 460; 700 F.; Sept. 11, 1929; 33 mm; Adult ♂
No. 13,461; Net 465; 800 F.; Sept. 12, 1929; 36 mm; Adult ♂
No. 13,575; Net 479; 600 F.; Sept. 20, 1929; 88 mm; Trans. Adol. ♀
No. 13,630; Net 486; 700 F.; Sept. 21, 1929; 50, 270 mm; Trans. Post-larva, Adult ♀
No. 13,718; Net 495; 800 F.; Sept. 23, 1929; 44, 60 mm; Post-larva, Trans. Adol. ♀
No. 13,848; Net 515; 800 F.; Sept. 27, 1929; 36 mm; Adult ♂
No. 14,712; Net 540; 700 F.; May 6, 1930; 40 mm; Adolescent ♂
No. 14,988; Net 576; 700 F.; May 14, 1930; 35 mm; Adolescent ♂
No. 15,093; Net 589; 700 F.; May 17, 1930; 35 mm; Adult ♂
No. 15,654; Net 646; 600 F.; May 29, 1930; 48 mm; Post-larva ♂
No. 15,871; Net 680; 700 F.; June 7, 1930; 41 mm; Adult ♂
No. 15,967; Net 699; 700 F.; June 13, 1930; 37, 40 mm; Adult ♂
No. 16,526; Net 759; 700 F.; July 2, 1930; 38, 40 mm; Adult ♂
No. 16,645; Net 770; 700 F.; July 4, 1930; 38 mm; Adult ♂
No. 16,721; Net 778; 700 F.; July 5, 1930; 33 mm; Adult ♂
No. 16,776; Net 785; 600 F.; July 7, 1930; 42 mm; Adult ♂
No. 16,842; Net 792; 600 F.; July 8, 1930; 48, 75 mm; Trans. Post-larva, Trans. Adol. ♀
No. 17,033; Net 797; 500 F.; July 15, 1930; 45, 47 mm; Post-larva ♂, Adolescent ♀
No. 17,056; Net 799; 700 F.; July 15, 1930; 37 mm; Adult ♂
No. 17,157; Net 806; 700 F.; July 16, 1930; 34 mm; Adult ♂
No. 17,202; Net 807; 800 F.; July 16, 1930; 36 mm; Adult ♂
No. 17,536; Net 825; 800 F.; Sept. 1, 1930; 38 mm; Post-larva ♂
No. 17,600; Net 829; 600 F.; Sept. 2, 1930; 36 mm; Adult ♂
No. 17,784; Net 838; 600 F.; Sept. 3, 1930; 40 mm; Adolescent ♂
No. 17,790; Net 839; 700 F.; Sept. 3, 1930; 37 mm; Adolescent ♂
No. 18,009; Net 854; 600 F.; Sept. 6, 1930; 35 mm; Trans. Adol. ♂
No. 18,037; Net 858; 1000 F.; Sept. 6, 1930; 35 mm; Trans. Adol. ♂
No. 18,063; Net 859; 500 F.; Sept. 8, 1930; 43 mm; Adolescent ♀
No. 18,091; Net 861; 700 F.; Sept. 8, 1930; 40 mm; Trans. Adol. ♂
No. 18,295; Net 866; 700 F.; Sept. 10, 1930; 33 mm; Trans. Adol. ♂
No. 18,395; Net 875; 600 F.; Sept. 11, 1930; 37 mm; Adolescent ♂
No. 18,444; Net 880; 500 F.; Sept. 12, 1930; 40 mm; Post-larva ♀
No. 18,629; Net 892; 800 F.; Sept. 15, 1930; 117 mm; Trans. Adol. ♀
No. 18,836; Net 917; 600 F.; Sept. 19, 1930; 28 mm; Larva
No. 18,848; Net 919; 700 F.; Sept. 19, 1930; 36 mm; Post-larva ♂
No. 19,153; Net 921; 500 F.; Sept. 20, 1930; 190 mm; Adult ♀
No. 20,532; Net 984; 600 F.; June 2, 1931; 33 mm; Adult ♂

No. 20,658; Net 999; 700 F.; June 5, 1931; 40 mm; Adult ♂
No. 20,821; Net 1016; 500 F.; June 15, 1931; 47 mm; Adolescent ♀
No. 20,872; Net 1022; 700 F.; June 16, 1931; 36, 39 mm; Adult ♂
No. 21,472; Net 1095; 600 F.; July 29, 1931; 44 mm; Trans. Post-larva ♀
No. 21,802; Net 1122; 600 F.; Aug. 3, 1931; 40 mm; Post-larva ♂
No. 21,937; Net 1137; 600 F.; Aug. 6, 1931; 40, 267 mm; Post-larva ♂, Adult ♀
No. 22,161; Net 1156; 500 F.; Aug. 10, 1931; 63 mm; Trans. Adol. ♀
No. 22,221; Net 1165; 900 F.; Aug. 11, 1931; 38 mm; Adult ♂
No. 22,255; Net 1169; 700 F.; Aug. 12, 1931; 40 mm; Adult ♂
No. 22,877; Net 1175; 600 F.; Aug. 14, 1931; 40 mm; Post-larva ♂
No. 22,476; Net 1184; 800 F.; Aug. 15, 1931; 242 mm; Adult ♀
No. 22,618; Net 1200; 600 F.; Aug. 19, 1931; 36 mm; Adult ♂
No. 22,673; Net 1210; 1000 F.; Aug. 20, 1931; 39 mm; Adult ♂
No. 22,783; Net 1225; 1000 F.; Aug. 26, 1931; 100 mm; Trans. Adol. ♀
No. 22,841; Net 1235; 500 F.; Aug. 29, 1931; 34 mm; Adult ♂
No. 22,949; Net 1242; 600 F.; Aug. 31, 1931; 28 mm; Trans. Adol. ♂
No. 23,002; Net 1249; 700 F.; Sept. 1, 1931; 32 mm; Adult ♂
No. 23,054; Net 1255; 600 F.; Sept. 1, 1931; 37 mm; Adult ♂
No. 23,097; Net 1260; 500 F.; Sept. 4, 1931; 120 mm; Trans. Adol. ♀
No. 23,100; Net 1261; 600 F.; Sept. 4, 1931; 35 mm; Adult ♂
No. 23,148; Net 1270; 500 F.; Sept. 7, 1931; 45 mm; Adolescent ♀
No. 23,163; Net 1271; 600 F.; Sept. 7, 1931; 32 mm; Adult ♂
No. 23,286; Net 1286; 900 F.; Sept. 10, 1931; 45, 51 mm; Post-larva ♂, Trans. Adol. ♀
No. 23,331; Net 1294; 900 F.; Sept. 12, 1931; 36 mm; Adult ♂
No. 23,350; Net 1296; 600 F.; Sept. 14, 1931; 36, 40 mm; Post-larvae ♂
No. 23,366; Net 1297; 700 F.; Sept. 14, 1931; 35 mm; Adolescent ♂
No. 23,545; Net 1308; 100 F.; Sept. 16, 1931; 16, 17, 20 mm; Larvae
No. 23,512; Net 1309; 100 F.; Sept. 16, 1931; (8), 18 to 25 mm; Larvae
No. 23,664; Net 1326; 600 F.; Sept. 19, 1931; 35 mm; Adolescent ♂
No. 23,900; Net 1332; 600 F.; Oct. 28, 1931; 30 mm; Trans. Adol. ♂
No. 23,941; Net 1337; 600 F.; Oct. 29, 1931; 45 mm; Postlarva ♀

The following specimens have been cleared and stained in order to study the skeleton: Nos. 8,733 (KOH No. 2019); 10,352 (KOH No. 2015); 10,476 (KOH No. 2021); 11,076 (KOH No. 328a); 11,087 (KOH No. 329); 11,088 (KOH No. 328b); 13,630a (KOH No. 2023); 15,967a, b (KOH No. 2028a, b); 16,776 (KOH No. 2029); 18,395 (KOH No. 2025); 18,444 (KOH No. 2024); 20,658 (KOH No. 1185); 20,821 (KOH No. 2020); 21,472 (KOH No. 2022); 21,937 (KOH No. 2013); 23,331 (KOH No. 1184); No. 23,350a (KOH No. 1025); 23,545b (KOH No. 1015b); 23,545c (KOH No. 1015c); 23,512h (KOH No. 2026).

The following material has been filed: Colored plates B277 and

B651; outline drawings B957–B986 incl; photographs B5361-L, B5389-L, B5585, B5587, B6215-L, B6275.

A specimen of *Idiacanthus panamensis* measuring 360 mm in standard length was used in connection with the study of the osteology of *I. fasciola* for purposes of comparison. This exceptionally large female (No. 5982, KOH No. 29) was taken by the Arcturus Oceanographic Expedition of the New York Zoological Society in the Gulf of Panama in May, 1925 at a depth of 750 fathoms.

Synonymy and References

Idiacanthus fasciola:

Peters 1876, p. 847. (2 specimens; 50, 130 mm; surface; north of Australia and north of New Guinea; *type specimens*).

Goode and Bean 1895, p. 128. (Mention of types).

Brauer 1906, p. 60; figs. 17–20; pl. iv, figs. 2–3. (2 specimens; 180, 147.5 mm; 594–2500 m.; off Sumatra and between Chagos and Seychelles Islands; also 1 young specimen, 2000 m, west of Chagos.

Brauer 1908, pp. 64, 176, pl. XXVI, figs. 14–27; pl. XXVII, figs. 1–14. (Structure of light organs and eyes).

Weber 1913, p. 15. (2 specimens; 45, 180 mm; 1536, 1600 m; Manipa Strait and Halmahera Sea).

Weber and Beaufort 1913, p. 108, fig. 37. (Records of occurrence in Indo-Australian region and description of Weber's "Siboga" specimen).

Parr 1927, p. 116; fig. 62. (4 specimens; 80 to 225 mm; 6000–10,000 ft. wire; Bermuda and Bahamas).

Beebe 1929, p. 13 (1 specimen; 122 mm; 600 fath.; Hudson Gorge).

Regan and Trewavas 1930; p. 129; figs. 20B, 22, 23, 125, 126. (250 advanced female specimens: 46 to 276 mm; 0–3000 m. wire; Atlantic. 30 so-called post-larvae (young females and young and adult males); 33 to 44 mm; 300–500 m. wire; Atlantic. 1 previously unrecorded British Museum specimen; 104 mm; Indian Ocean.

Roule and Angel 1933, p. 24. (10 specimens; 115 to 320 mm; 0–250–4000 M; eastern Atlantic.

Beebe 1933c, p. 39. (Preliminary account of the present Bermuda material).

Bathyophis ferox:

Günther 1878, p. 181. (1 specimen; 195 mm; 2750 fath.; middle of North Atlantic; preliminary type description).

Idiacanthus ferox:

Günther 1887, p. 216, pl. LII, fig. D. (Supplementary description of type).

Goode and Bean 1895, p. 129, fig. 151. (Mention of type).

Jordan and Evermann 1896, p. 605. (Mention of type).

Murray and Hjort 1912; pp. 86, 87, 612, 618; fig. 67b. (10 or more specimens; at least up to 220 mm; surface to 1500 fath.; between Azores, Canaries, and northwest Africa).

Stylophthalmus paradoxus (partim):

Brauer 1902, p. 298. (Preliminary type description).

Brauer 1906; p. 67, pl. V, figs. 1–7. (Detailed description. Entire series, only some of which were *Idiacanthus*, contained 35 specimens; 10.5 to 40 mm; 1500 to 4000 m.; west coast of South Africa, Antarctic off Bouvet Island, Indian Ocean).

Brauer 1908, p. 178. (Dissection of eye).

Beebe 1929, p. 9. (2 specimens; 4.3 and 41 mm; 600 fath.; Hudson Gorge. *Partim*).

Beebe, 1933a, p. 180. (Records of shallow water occurrences of Bermuda specimens. *Partim*).

?Idiacanthus aurora:

Waite 1916, p. 53, pl. V, fig. 1. (1 specimen; 408 mm; 1450 fath.; off Macquairie Island, Australia).

Regan 1916a, p. 378. (Suggestion as to the synonymy of *I. aurora* with *I. niger*).

Archey 1922, p. 296. (Comparative measurements of *I. aurora* and *I. niger*).

Regan and Trewavas 1930, p. 129. (Tentative synonymy of *I. aurora* with *I. fasciola*).

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